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Case Studies

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HIGHWAY RUNOFF/DRAINAGE IMPACTS

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ABSTRACT

The Federal Highway Administration has undertaken a four-phased research program on nonpoint source pollution from highway operations. The objectives of this program are to characterize highway stormwater runoff; identify sources, mechanisms of transport, and fate of pollutants within the right-of-way; determine the magnitude and extent of impacts to receiving waters; and develop guidelines to implement cost-effective measures to protect water resources. A multistudy program has developed a significant national highway stormwater runoff data base. The objective of these studies was to identify and quantify pollutants found in runoff from operating highways. Research is underway to develop a design procedure to predict pollutant loading from highways. This study also identified factors that influence the transport and fate within the right-of-way. Results of this research were used to identify cost-effective measures to minimize impacts. An extensive receiving water study has investigated the effects of highway runoff on receiving water environment. Guidelines were developed for assessing water resources impacts from highways. An evaluation and synthesis of nonpoint source runoff mitigation has identified cost-effective measures for highway stormwater and guidelines to assist highway agencies in identifying potential problems and implementing mitigation. An important product of this study was identification of ineffective measures. Research is underway to develop performance criteria and design specifications for retention, detention, and overland flow systems. A highway runoff training program is being prepared to transfer the technology developed from this program.

Interactions of the highway system with the Nation's water resources are continuous and far reaching. Every mile of highway daily affects adjacent watersheds. Each stage of the highway process (planning, location, design, construction, operation, and maintenance) may have an impact on water resources. Protecting the quality of water, wetlands, and related aquatic resources is an important facet of improving the total environment; thus, it is essential that pollution from highway sources be identified and reduced as much as possible. To accomplish this objective, the environmental effects must be identified and measured.

Construction, operation, and maintenance of the highway system can contribute a wide variety of pollutants to surrounding surface and subsurface waters through natural runoff. The sources of runoff pollutants and the immigration pathways and transport mechanisms from the roadway surface to the receiving water must be determined to enable efficient mitigation. This will minimize unnecessary or ineffective treatment procedures. Where necessary, methods of treating or minimizing the pollutants in runoff must be devised.

A cooperative Federal and State research and development program was begun to identify and quantify the effects of highway runoff and develop measures for protecting the environment from any adverse effects. The FHWA, charged with the responsibility for protecting the environment from pollution from highway sources, has approached the problem in a four-phase research program. The objective of each phase is as follows:

1. Identify and quantify the constituents of highway runoff.
2. Identify the sources of these pollutants and migration paths from the highway to the receiving water.
3. Analyze the effects of these pollutants in receiving waters.
4. Develop the necessary abatement/treatment methodology for objectionable constituents.

Phase 1 included not only identification and quantification of highway runoff constituents, but also development of a predictive procedure to be used analytically for preparation of Environmental Impact Statements (EIS). An extensive literature review was conducted at the beginning of the Phase 1 study, and a current state-of-the-art report was prepared at the end of the study in March 1978. A Procedural Manual, written for State highway personnel, details procedures for establishing and conducting a highway runoff monitoring program.

Results of the Phase 1 study have been documented in a six-volume publication titled, Constituents of Highway Runoff. The predictive procedure developed from this study's data will provide highway designers and other interested individuals/agencies with a simplified tool to predict the quantity and quality of rainfall-generated highway runoff. The procedure is made up of four components corresponding to the following functions:

1. Rainfall—runoff,
2. Pollutant buildup,
3. Pollutant washoff,
4. Constituent loadings.

Rainfall–Runoff. The predictive procedure calculates the volume of runoff for a given rainfall volume using equations developed from monitoring data and regression analyses. Since the rainfall–runoff relationship depends on site characteristics, an equation was developed for each of three basic site types defined from general site characteristics of the six monitoring locations. The three site types are:

Type 1: all pavement, bridges or overpasses

Type 2: partially paved with curbs and inlets along the paved area (30 to 40 percent paved)

Type 3: rural sites with flush shoulders, grassy ditch conveyance to inlets (20 to 30 percent paved).

The resultant equations relating runoff volume to rainfall volume for the three site types are as follows:

Type I

$$Q = 0.969\,R - 0.019$$

Type II

$$Q = 0.470\,R^{1.369}\,DD^{-0.086}$$

Type III

$$Q = 0.845\,R^{1.892}\,DD^{-0.654}$$

where; Q = runoff volume (inches)
R = rainfall volume (inches)
DD = dry days to last storm event

A linear equation produced the most significant correlation when regression analysis techniques were applied to monitoring data for the Type I site. For the Type II and Type III sites, the most significant equations were obtained by log-normalized values for total rain and dry days.

The average runoff rate in inches per hour has the highest correlation with the actual pounds of pollutant discharged as determined through regression analyses. For the predictive procedure to calculate duration runoff, rainfall duration is used in a series of equations to produce the runoff duration for each event. Prestorm history and site characteristics are again used to predict runoff duration. Equations relating rainfall, runoff duration, dry days and site characteristics were developed from the monitoring program's extensive data base. The duration of runoff and runoff volume are then used as average runoff intensity, the mechanism for washoff of pollutants from the highway area.

Pollutant Buildup and Washoff. Buildup and washoff of pollutants from the highway drainage area are predicted using a carrier pollutant as the mechanism of each process. The carrier pollutant is total solids since it had the best correlation with 16 other commonly used water quality parameters. Buildup of total solids on the drainage area is simulated in the model using a buildup rate K_1, calculated in the following manner:

$$I_1 = 0.007\,(ADT^{0.89})$$

where; K_1 = total solids in lb/mi/day
ADT = average daily traffic in vehicles per day

The K_1 factor is then used at the modeling site to accumulate solids on the drainage area surface during the prestorm dry period.

Removal of the carrier pollutant from the highway area is predictively accomplished using the standard washoff equation with the following format:

$$P_D = P_O\,(1 - e^{-K_2 r})$$

where; P_D = pounds of total solids washed off
P_O = initial surface loading (pounds of total solids)
= K_1 × dry days × site length in miles
K_2 = washoff coefficient
r = average runoff intensity in in/hr

K_2 values are selected in the predictive procedure based upon site characteristics and range from 5.0 to 12.0.

Constituent Loadings. The predictive procedure has, to this point, determined the mass of total solids washed off for each rainfall event. The transformation of total solids into pounds of biochemical oxygen demand (BOD), heavy metals, nutrients, or any other of 16 available parameters is performed using individual equations for each site. These equations have been developed from more than 1,000 individual chemical analyses from the monitoring program for correlation of parameters. Total loading (lb) and concentration (mg/L) of each parameter is listed in the predictive procedure output.

Predictive Procedure Results. The predictive procedure was incorporated into a set of equations for input to a computer. This format allows simulation of runoff quantity and quality from continuous precipitation records covering months or years of data. Output was compared to measured quality data from five of the study's monitoring sites. Accuracy for predicting the total solids load for the entire monitoring period at each site was 12 percent low at Milwaukee I–794, 15 percent high at Milwaukee Hwy. 45, 15 percent high at Nashville, 1 percent high at Harrisburg and 37 percent high at Denver. The model output was verified with independent data from another FHWA project in Dallas, TX. For the Texas site, the model predicted total solids loadings 34 percent higher than the measured loadings. Further research should refine the predictive procedure as additional data become available.

Predictive Procedure Limitations. Because of complex interactions of rainfall, runoff, and traffic on a highway, following are some limitations of the predictive procedure needing improvement during future research.

1. The predictive procedure assumes the highway area to be uniformly characterized by the three site types listed. Significant variations in a site may have widely varying results.
2. The predicted pounds of total solids washed off during a rainfall event depend on model prediction of surface load at the start of the storm. If surface load is underestimated, the pounds discharged will be low.
3. The use of average runoff intensity to remove pollutants is the quickest method and easiest to calculate. Peak runoff intensities during the runoff hydrograph may be more accurate, but are too involved for this procedure.
4. Long dry periods and overlapping storms present predictive problems in determining the prestorm surface load.
5. Construction activities are difficult to simulate unless monitoring data are available to determine K_1 values.

To accomplish the objectives of Phase II, a literature search and field monitoring program was conducted. The field monitoring program was divided into two categories: pollutant source investigations and migration/transport/fate studies.

Sources of many highway pollutants were adequately documented in the literature, while pathogenic indicator bacteria, asbestos, and PCB's were further investigated. As part of FHWA's Phase I study of the constituents of highway runoff, significant data were collected with respect to the presence and quantification of highway runoff constituents; however, a gap remained in understanding the origin and fate of these constituents within the highway environment.

Data were collected to evaluate the qualitative and quantitative aspects of background pollutant loading to the highway system, pollutants originating from the highway system, and the mechanism of pollutant dispersion within the transfer out of the highway system. Variables affecting pollutant deposition, accumulation, and removal were also measured. These variables include traffic characteristics, highway design, maintenance activities, surrounding land use, and climatic conditions. Field studies were conducted for a minimum 12-month period to evaluate seasonal effects on these processes. Field monitoring can be categorized as follows:

1. Atmospheric deposition
2. Total suspended particulates
3. Saltation
4. Highway surface loads monitored through sweeping/flushing studies
5. Runoff quantity and quality
6. Groundwater percolation monitored by lysimeters
7. Soil and vegetation studies
8. Traffic characteristics
9. Highway maintenance data
10. Climatological data

Precipitation at Milwaukee, Wisconsin, I–94, the most urbanized and industrialized of the sites monitored, had the highest maximum and median value for most quality parameters (mg/L). However, for many constituents Sacramento, California, U.S–50, Efland, North Carolina, I–85, and Harrisburg, Pennsylvania, I–81 had larger loadings per precipitation event (mg/m^2) than Milwaukee, probably because of the larger total volume per rainfall event observed. Deposition of chlorides via precipitation was higher during the winter than summer at Milwaukee and Harrisburg, possibly attributable to chloride aerosols from street and highway salting activities.

Although enteric bacteria (total coliform, fecal coliform, and fecal streptococci) were present in paved and unpaved runoff at the Milwaukee site, they were not detectable in precipitation, dustfall or ambient air samples. Apparently, the roadway surface is periodically seeded with debris containing enteric bacteria. A possible source could be trucks carrying livestock and stockyward waste; the FC/FS ratios monitored in runoff indicate the enteric bacteria present on roadway surfaces to be largely of animal origin. Bacteriological data also indicated that fecal coliforms remained viable within roadway dust and dirt for relatively long periods of time (at least 7 weeks). Fecal coliform and fecal streptococcus bacteria remain viable in stagnant storm sewer water for at least 13 days.

Asbestiform material was not detected in precipitation, runoff, dustfall, or air samples at the Milwaukee I–94 site. These results, consistent with those of FHWA's Phase 1 study on runoff constituents, indicate that the quantity of asbestiform material present in the highway systems is either below detection limits or is difficult to detect.

Low levels of polychlorinated biphenyls were detected in soil, vegetation, precipitation, highway surface dust, and dirt and runoff samples. Runoff studies indicated that PCB's in the highway environment are transported from that environment via runoff during storm events. Also, indicated sources of PCB in highway runoff include precipitation, highway surface dust and dirt, and contaminated soil eroded by the runoff from unpaved surfaces adjoining the highway.

Field studies evaluated the quantitative and qualitative aspects of background pollutant deposition to the highway system (source studies), pollutant accumulation within the highway system, and the mechanism of pollutant transport within and out of the highway system.

Bulk precipitation data (wet and dry atmospheric deposition) were collected at each site to establish the level of pollutants migrating from the highway to the surrounding environment through atmospheric processes. The area adjacent to the highway receiving TPM (total particulate matter) and associated metals (impacted area) was defined using bulk precipitation and 1-cm soils data. One-cm soils data were used because accumulation of highway-related metals from atmospheric deposition should be reflected in the topsoil layer of areas adjacent to the highway. The impact area was defined to be approximately 35 m from the edge of pavement at Milwaukee, 35 m at Sacramento, 15 m at Harrisburg, and 12 m at Efland. The smaller impact areas at Harrisburg and Efland are probably a function of average daily traffic (27,800 and 25,500 vehicles per day at Harrisburg and Efland, respectively, and 116,000 and 85,900 vehicles per day at Milwaukee and Sacramento, respectively). Urban sites showed TPM loadings four times higher than rural sites. Background metals deposition was similarly higher.

Data indicated that bulk precipitation as monitored during this study provided generally precise measurements of TPM deposition, but that localized effects of vehicular turbulence and severe meteorological conditions can decrease the accuracy.

Another mechanism for removing pollutants from the highway through the atmosphere is saltation. The quantity of saltating particles (sand sized particles injected into the atmosphere by vehicular turbulence) and highway-generated TPM reaching areas adjacent to the highway appears to be related to:

1. Average daily traffic
2. Wind speed and direction
3. Available surface load (seasonal variation)
4. Highway drainage design
5. Proximity of travel lanes to right-of-way area
6. Landscape features near the highway affecting wind patterns.

Monitoring of runoff from the paved and unpaved areas was segregated to determine pollutant loadings leaving the highway drainage system and to examine the hydraulics of pollutant movement in the drainage scheme. At the Milwaukee and Sacramento sites (curb and gutter drainage design), the unpaved area contributed negligible amounts to the total constituent load, while at Harrisburg (flush shoulder drainage design) the unpaved area contributed approximately 17 percent of the total load for most constituents.

Runoff data indicated that the highway system has a large capacity to buffer the runoff of acid precipitation before it reaches the surrounding environment. Ground water percolation data also indicated that the soil system adjacent to the highway sections monitored at Milwaukee and Sacramento had considerable buffering capacity against acid rain while the Efland and Harrisburg soil systems had limited buffering capacity. The prevalence of acid rain in the United States and the apparent ability of highway systems to buffer it may have important implications when considering pollutant migration from the highway. The solubility of metals is a function of pH (generally higher solubilities occur at the extremes of the pH scale) and the quantity of anionic complexing agents and organic matter present. Soluble metals would be easier to remove from the highway surface, would tend to migrate further, and would be readily assessed for bioaccumulation.

Highway runoff at Milwaukee, the site with the highest average daily traffic, had the highest solids loadings and generally the highest loadings for most parameters. Sites where deicing agents were applied showed increases in total solids, sodium, and chloride loadings during winter periods. The deicing salt used at Milwaukee was analyzed for contaminants. The salt analyzed contained lead, zinc, chromium, copper, cadmium, nickel, and cyanide. The loading of cyanide, an anticake compound used to keep salt granular, was approximately 0.79 kg/km/yr. Based upon loading values, rock salt was also an important source of cadmium and nickel. At Efland, deicing agents (rock salt and calcium chloride/sand mixture) were also analyzed for contaminants. Lead, iron, chromium, copper, and cyanide were present in the sample analyzed, but in generally lower levels than at Milwaukee. The contaminants associated with deicing agents vary with the source of the deicing agent and additives used.

Solids and associated pollutants tend to accumulate in the distress and median lanes, while more soluble pollutants tend to be uniformly distributed across the distress, median and travel lanes. Apparently, vehicular turbulence moves any solids from the travel to the outer lanes. Lateral variation in surface load at a given time appears to be a function of profile grade and other factors including: inlet placement, seasonal characteristics, maintenance activities, and traffic patterns.

Commercial sweeper efficiency studies performed at Milwaukee showed that commercial sweepers' efficiency was generally highest for solids and their associated constituents and lowest for the more soluble constituents. Sweeper efficiency was also higher in summer than in spring. The surface load, more compacted in the spring than in summer, was presumably more difficult to remove by surface sweeping.

Metals and sodium concentrations were generally higher in the topsoil layers (major rooting zone usually 10-cm deep) than substrate layers, and decreased with distance from the highway. Chlorides did not show this gradient. Lysimeter data indicated that chlorides are removed from the topsoil layer shortly after spring thaw.

At the Milwaukee site litter was highest for the near highway samples although biomass production was slightly higher for samples obtained further from the highway. At the Sacramento site no vegetation grew near the highway. This would be expected since the soils next to the highway were sandy, low in organic matter, high in soluble salts, low in nutrients, and high in lead and zinc. Normal ecosystem processes may be affected in areas immediately adjacent to the highway (1–2 m), especially near highways with high average daily traffic (ADT greater than 85,000 vehicles per day).

The third phase of FHWA's administrative contract research program, Effects of Highways on Water Resources, is underway. The objective of this research is to:

1. Determine the magnitude and extent of the impacts of highway stormwater runoff on receiving water quality and aquatic biota;

2. Formulate procedural guidelines for assessing impacts of highway stormwater runoff;

3. Provide guidelines for conducting field studies to determine effects of highway runoff on receiving waters.

An extensive field monitoring and laboratory analysis program has been conducted at three sites: a stream site in southeastern Wisconsin (Wisconsin Highway 15), a stream site adjacent to I–85, west of Efland, North Carolina, and a lake site north of Milwaukee, Wisconsin. Interim results indicate no significant impact to receiving water ecology for highway facilities with low to medium ADT (less than 30,000).

Acute toxicity bioassays of undiluted highway runoff from Wisconsin Highway 15 (ADT 12,000) and I–94, Milwaukee (ADT 120,000) simulated worse case shock loading on the receiving waters for several days. Some assumptions are implied: (1) the quality of the receiving water may be temporarily degraded by runoff from a storm event, but will rapidly return to its previous state; (2) detrimental substances in the runoff water are flushed out of the receiving waters and do not linger; and (3) detrimental effects on the biota of the receiving water would be from direct toxicity, not indirect or delayed effects of assaults on other components of the system.

Neither of the undiluted highway runoff samples was acutely toxic to the fathead minnow. The fish exposed to the runoff water swam sluggishly in comparison with those in the control water, thereby implying that the runoff water imposed a sublethal stress on the fish. The stress was removed when the fish were returned to the control water at the end of the exposure period.

The isopod *Asellus* was insensitive to exposure to undiluted highway runoff water from either source for 4 days. No delayed responses were observed. The size of the organisms did not influence the results of the assay.

The amphipod *Gammarus* was sensitive to exposure to undiluted water from Highway 15. Of the observed mortality, 40 percent was attributed to direct toxicity of the water. Fewer deaths were observed in the assay of I–94 water than in the control water within the same experiment, although the difference was not statistically significant. No additional mortality because of delayed effects was demonstrated. This organism was the most difficult to maintain in the laboratory, and mortality of the control group was always greater than 20 percent after 4 days. Cannibalism was observed in the test vessels, indicating possible nutritional stress. Any toxic stress from the runoff water would then be superimposed on the physiological stress. The conditions under which the assays using *Gammarus* were performed therefore represent a worst case. The size of the animals did not influence the results of the assay.

Mayfly nymphs, genus *Hexagenia,* were slightly sensitive to undiluted highway runoff water, but no more than 20-percent mortality was observed in any test vessel. No delayed response to toxins in the water was demonstrated, and mortality was not confined to a single size of the nymphs. Exposure to I–94 water did not inhibit the nymphs from hatching into adults.

The cladoceran, *Daphnia,* was not lethally sensitive to Highway 15 runoff water in a 96-hr flowthrough assay, nor to I–94 water in a 48-hr static assay. The animals were under stress when exposed to the I–94 water, relative to the control group, but they were not dead after 48 hours.

Algal assays, using *Selenastrum*, demonstrated adverse effects of undiluted runoff water from both Highway 15 and I–94 on algal growth. The algal assay is not a short-term, acute toxicity test, but rather a chronic toxicity test. The time frame for chronic tests is not realistically representative of actual conditions; however, as a bioassay tool it may indicate that a water source inhibits algal growth, and may implicate the causative agent for the inhibition.

Snowmelt runoff water from Highway 15 contained both heavy metals and remarkably elevated concentrations of salt ions from deicing chemicals application. The results of the algal assay demonstrated a complex interaction between the metals, salts, a metal chelator, and a phosphorus nutrient. Metals inhibition may have been present but was not clearly resulting from compounding effects of salt stress. The results of the assays of I–94 water demonstrated a probable heavy metal stress on the algae. When metals were chelated, the algae were phosphorus limited.

ROCK CREEK RURAL CLEAN WATER PROGRAM: THE EXPERIMENT CONTINUES

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INTRODUCTION

Rock Creek in Twin Falls County, Idaho, has long been recognized as one of the most severely degraded streams in the State. Both point and nonpoint sources of pollution have contributed to this problem. The 1972 Federal Water Pollution Control Act (P.L. 92-500) stimulated pollution abatement efforts, and since then both State and Federal programs have been directed toward pollution abatement in Rock Creek. The National Pollution Discharge Elimination System (NPDES) program essentially has eliminated point source discharges from food processing plants, fish hatcheries, and the Twin Falls sewage treatment plant. Removing these point sources reduced bacterial contamination and nutrient loading, increased the dissolved oxygen level, and improved aesthetics in Rock Creek (Martin, 1984).

Agricultural nonpoint sources, however, continue to cause severe pollution problems within the Rock Creek drainage. Irrigation return flows to the creek contain high concentrations of suspended sediment and related agricultural pollutants such as phosphorus, nitrogen, and fecal coliform bacteria. During the irrigation season, the water from Rock Creek can be traced as a brown muddy streak at its confluence with the Snake River.

This paper will present and briefly discuss the history, major activities, and progress in restoring the health of Rock Creek through the Rural Clean Water Program.

PROGRAM EVOLUTION

The Idaho Department of Health and Welfare, Division of Environment (IDHW) has conducted several water quality studies over the years in Rock Creek. An initial survey in 1960 identified public health problems (Idaho Dep. Health Welf. 1960). Water quality studies from 1972 to 1974 (Clark, 1975) have identified the impact of point source discharges in the Twin Falls area on Rock Creek. Another water quality survey in 1977 recorded the status of the upper segment from the townsite of Rock Creek to the Forest Service boundary (Schaefer and Bauer, 1979). In addition, a water quality trend station has been sampled monthly since 1969.

Because of the continuing water quality problems, the Idaho Agricultural Pollution Abatement Plan (Idaho Soil Conserv. Comm.) identified Rock Creek as a priority stream segment in 1979. That year, the Snake River and Twin Falls Soil Conservation Districts applied for and obtained a planning grant, under Section 208 of the Federal Water Pollution Control Act, to develop a detailed water pollution abatement plan for Rock Creek.

In 1980 Rural Clean Water Program (RCWP) funds were obligated to begin the Rock Creek project. The RCWP came about as a result of a provision in the 1977 Clean Water Act amendments to FWPCA. Twenty-one watersheds throughout the country were eventually selected for planning, implementation, and monitoring under the RCWP.

The Rock Creek RCWP was approved for funding with the intention that specific agricultural pollutants be significantly reduced This program's objectives are to reduce sediment loading 70 percent, total phosphorus 60 percent, total nitrogen 40 percent, fecal coliform bacteria 70 percent, and pesticides 65 percent through best management practices (BMP's). The BMP's were to reduce the amount of sediment and sediment-related pollutants entering Rock Creek from agricultural lands and the amount of animal wastes entering the creek by applying animal waste management systems.

DESCRIPTION OF PROJECT AREA AND IRRIGATION SYSTEM

Rock Creek is in the south central part of Idaho, in Cassia and Twin Falls counties. From its headwaters in the Sawtooth National Forest in western Cassia County the creek flows northwest, approximately 67 km (41.6 mi), to the Snake River, north of the city of Twin Falls. The entire watershed contains 80,292 ha (198,400 acres). The project area includes 18,211 ha (45,000 acres). Elevation within the entire watershed ranges from 2,432 m (7,977 ft) at the headwaters to 912 m (2,991 ft) at the mouth of Rock Creek. The stream gradient is fairly constant down to river kilometer 27. At this point the gradient substantially increases, being steepest the last 1.5 km (0.9 mi) before the confluence with the Snake River.

Soils in the lower watershed from the mouth to river kilometer 47 (mile 25) generally have thin, dark, silt loam and loam surface layers and very strongly calcareous subsoils. These soils vary in depth and are underlain by fractured basalt. The soils developed under arid conditions and in their natural state are low in organic matter. They are highly productive and highly erodible.

The Rock Creek project area watershed contains approximately 350 farms. The basic crops are dry beans, small grains, sugar beets, corn, dry peas, and alfalfa. All crops are irrigated because of low (8″ to 10″) annual precipitation. The majority of cropland is furrow irrigated.

Irrigation water is diverted from the Snake River and delivered at a regulated and measured rate through a network of canals owned and maintained by a private company, the Twin Falls Canal Company, from about mid-April through mid-October.

The developers of the irrigation tract used natural streambeds and other drainages as much as possible to deliver water to the fields ahd to carry runoff water away. Water is diverted from the high line and low line canals to the laterals. Laterals are the heads of the drainages that deliver irrigation water to the farms and also carry runoff return flows to Rock Creek. Water is diverted from a lateral to the first field, and runoff from the first field is used on the next field with whatever additional water is needed from the lateral to provide adequate water supply for the second field. The method continues through each farm until the water reaches the next farm. The wastewater, or runoff, may enter the next farm directly or some portion may reenter the lateral (along with newly accumulated sediment and nutrients) and be diverted onto another farm further downstream. This system of water delivery continues through the length of the lateral until it discharges into Rock Creek.

Before the irrigation tract was developed, Rock Creek was historically fed mainly by snowmelt. Low flows occurred in summer and fall and high flows in late winter and spring. Irrigated agriculture changed these flow trends, greatly increasing the summer stream flow. Peak flow now occurs in September (Martin, 1984).

LANDOWNER PARTICIPATION IN THE RCWP

Without question, the critical key to success is landowner acceptance of this program, or any similar voluntary participation program, and the willingness to commit funds to implement practices which may not provide an immediate tangible benefit to the landowner's bank account or farm operations.

When the Rock Creek RCWP began in 1980 the agricultural market was healthy and initial interest and response for planning assistance were overwhelming—so overwhelming, in fact, that the local Soil Conservation Service staff were playing catch-up from the beginning. With some changes in staff along the way, it took almost 3½ years to service the backlog of requests for planning assistance.

About 1 year after the program began, the farm economy faltered and the number of requests steadily declined. By spring of 1984 there were no requests for planning assistance on file.

Surprisingly, the economic condition has not seriously crippled the project's goals, although a fourth straight year of depressed market prices could adversely affect remaining contracting and implementation goals. However, a sound foundation has been established by the local soil conservation districts and SCS staff. The project has been successful to date because landowners recognize the need for improvements. Most individuals knew that Rock Creek was degraded before the project was ever conceived. The farmers within the project are to be commended for their participation despite the poor economy.

COMPREHENSIVE MONITORING AND EVALUATION

The Comprehensive Monitoring and Evaluation phase of the Rock Creek RCWP is undoubtedly more technical and complex than the contracting and best management plan implementation phase. Idaho's Division of Environment is the principal agency responsible for monitoring stream flow and the water quality parameters outlined in the plan of work. The division monitors trends in water chemistry, benthic macroinvertebrates and game fish populations.

Other aspects of the monitoring program are being carried out by various State and Federal agencies. The U.S. Department of Agriculture (USDA)—Economic Research Service (USDA-ERS) and University of Idaho Agricultural Economics Department are jointly evaluating the social and economic impacts of installing best management practices. The Idaho Energy Resources Research Institute and University of Idaho Agricultural and Civil Engineering Departments, in cooperation with the USDA–Agricultural Research Service and University of Idaho Cooperative Extension Service, have attempted to develop a sediment generation and routing model for irrigation return flow. The Agricultural Research Service is also evaluating the effectiveness of individual sediment retention BMP's at the Snake River Conservation Research Center.

STRATEGY FOR MONITORING IMPLEMENTATION EFFECTS

The RCWP project watershed is divided into 10 subwatersheds, or subbasins, for individual analysis and comparison of data in relation to different levels of BMP implementation (Fig. 1). Monitoring stations were set up on the priority subbasins (1, 2, 4, 5, and 7). Monitoring stations were also established at key locations along Rock Creek (Fig. 2). Idaho Division of Environment staff have been collecting data at these locations since 1981.

The RCWP subbasins receive water from the High Line and the Low Line Canals. Subbasins also receive water from seeps occurring throughout the project. However, not all of these seeps contribute irrigation water and as such are not considered indicative of upstream water quality. RCWP subbasins 4, 5, and 7 are monitored where water is diverted from the canals into the major laterals. Subbasins 1 and 2 receive a combination of seep and canal water and are monitored as close to the source as possible. The laterals are also monitored near their points of discharge into Rock Creek. The amount of water delivered to the subbasins is controlled and the way it is used and distributed throughout the subbasins is controlled. Therefore, the hydrologic cycle that affects erosion and subsequent irrigation runoff is almost totally man-induced during the 6-month-long irrigation season.

The subbasins are monitored only during the irrigation season, biweekly from mid-April to mid-May, weekly from mid-May to early August, and biweekly again from early August to mid-October. The heaviest pollutant load from irrigation return flows occurs from mid-May to early August. Irrigation continues until a week or so before harvest, and most crops are removed by mid-October. The irrigation return flows move through drainageways that have basalt bedrock at or very near the surface and slope gradients that allow little deposition of sediment. Therefore, most of the pollutant load reaches Rock Creek. The resultant changes in water quality from the implementation of BMP's should be detectable at the downstream stations for each lateral where they discharge into the creek (Martin, 1984).

MONITORING RESULTS AND CONCLUSIONS

By the end of the 1983 irrigation season, the percent of land benefiting from BMP implementation ranged from none in the nonpriority subbasins (9 and 10) to 84 percent in subbasin 7. Annual levels of implementation will always fluctuate because of factors such as crop rotations, economics, and tillage practices. Along with changes in the weather, evaporation rates, irrigation demands and incoming (upstream) water quality, these factors will influence outgoing (downstream) water quality.

Sediment Loading

The most obvious effects of BMP's are seen in the drainageways closest to the site of implementation. Significant ($p \leq 0.01$) reductions in suspended sediment concentrations were measured at five of the six subbasin stations that discharge into Rock Creek. The suspended sediment concentrations at those five sites in 1983 averaged 55 percent less than the concentrations measured in 1981. Altogether, 45 percent of the acreage of those five sites

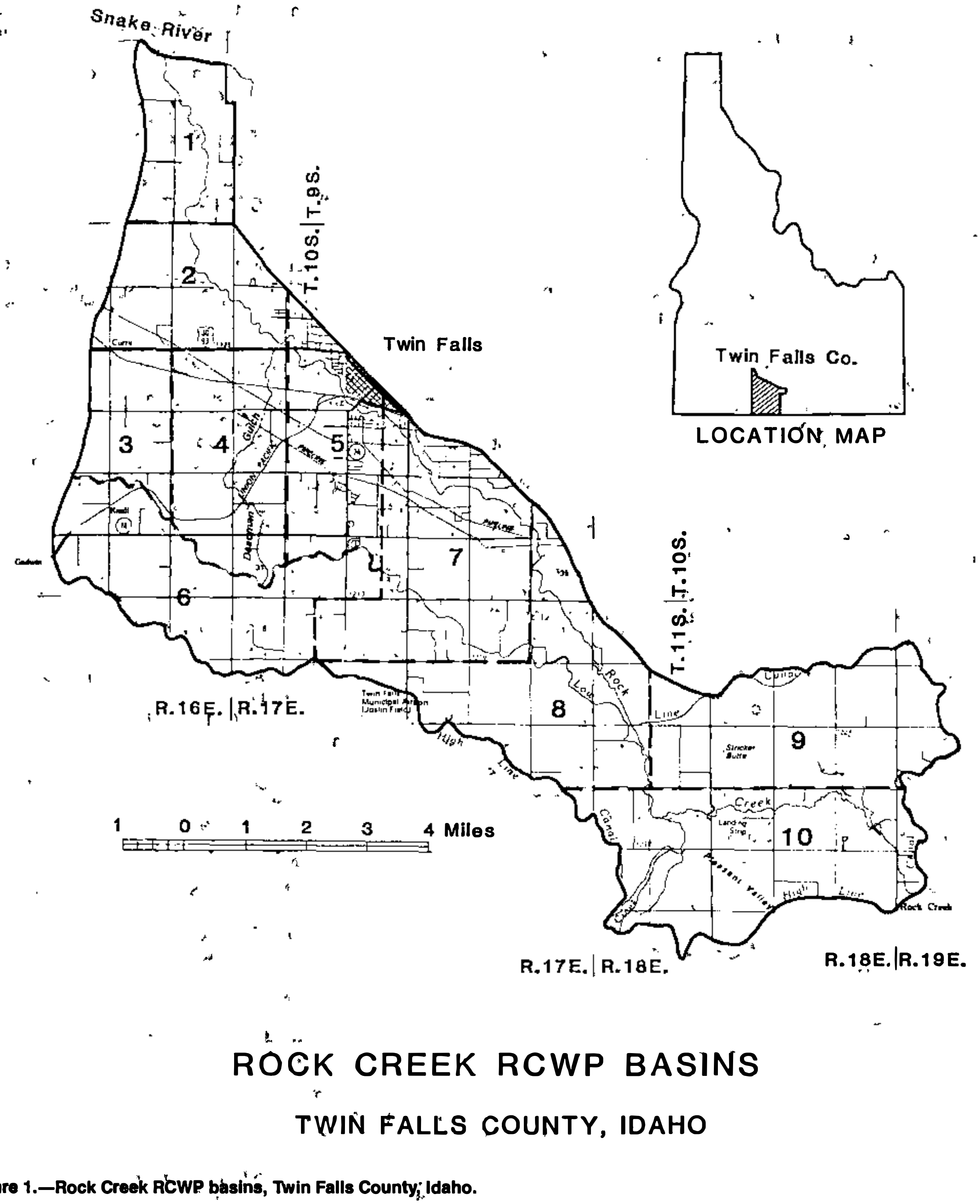

Figure 1.—Rock Creek RCWP basins, Twin Falls County, Idaho.

benefitted from BMP implementation upstream. Three of the Rock Creek monitoring sites had significant ($p < 0.01$) reductions in suspended sediment concentrations, with an average of 50 percent reduction from 1981 to 1983. It appears that the project objective of 70 percent reduction in the suspended sediment contributed to Rock Creek from the subbasins may be attained when all of the contracted BMP's are installed.

Phosphorus

The changes in concentrations of phosphorus (total and dissolved orthophosphate) in the study area were not as pronounced as suspended sediment. A significant ($p < 0.05$) reduction in total phosphorus concentration was measured at only one Rock Creek site, S-1. This site was the only one on Rock Creek to exhibit a significant ($p < 0.01$) decrease in dissolved orthophosphate from 1980 to 1983. Two subbasin sites, 2-2 and 4-3, had significant ($p < 0.01$) reductions in total phosphorus concentrations, 48 percent and 53 percent, respectively. Significant ($p < 0.01$) changes in dissolved orthophosphate concentrations were measured at subbasin sites 4-2 (35 percent increase) and 4-3 (42 percent decrease). The reason for the increase at site 4-2 is not yet understood. Both these stations also exhibited significant ($p < 0.01$) reductions in suspended sediment concentrations. The expected relationship of total phosphorus and suspended sediment has been inconsistent in the analysis to date. The project objective of 60 percent reduction of total phosphorus, however, still appears to be realistic and should be retained until further BMP implementation is attained and additional analyses are conducted.

Nitrogen

Analysis of the nitrogen data is divided into two components: Kjeldahl (organic) and inorganic. Significant ($p < 0.01$) reductions in Kjeldahl nitrogen concentrations were measured at all Rock Creek monitoring sites from 1981 to 1983, with an average decrease of 58 percent. Similar significant ($p < 0.01$) decreases in this parameter were measured at three subbasin stations, 2-2, 4-3, and 7-4, with an average of 55 percent reduction in Kjeldahl nitrogen concentration. The trends for inorganic nitrogen are inconsistent with suspended sediment concentration trends at both the Rock Creek and subbasin sites.

Rock Creek had two sites, S-3 and S-4, with significant ($p < 0.05$) increases that averaged 211 percent of 1981 values. Martin (1983) and others have noted that BMP's targeted at reducing suspended sediment appear to have insignificant effect on reducing inorganic nitrogen concentrations, but do have a dramatic impact on reducing Kjeldahl nitrogen concentrations. If the project objective of reducing total nitrogen by 40 percent is to be achieved it will apparently have to be met by the reduction of Kjeldahl nitrogen alone. It may be time to reevaluate this objective.

Fecal Coliform Bacteria

Bacterial contamination of Rock Creek from fecal coliforms was significantly ($p < 0.01$) reduced at Rock Creek monitoring sites S-3 and S-4. From 1981 to 1983 the concentration at these sites decreased 63 percent and 72 percent, respectively. From 1981 to 1983 only subbasin site 4-3 had significant ($p < 0.01$) reductions in fecal coliform bacterial concentrations. This pollutant decreased 70 percent at subbasin site 4-3 after an RCWP participant removed his cattle from the corrals through which this lateral flowed. The reason for reduction at Rock Creek site S-3 is perhaps the same. A large livestock operation was eliminated during this period; although no specific data were collected, this is very likely the cause for the measured difference at S-3. The probable cause for the reduction in fecal coliform bacterial concentrations at S-4, and in part the other noted locations, is a general decline in numbers of cattle owing to poor market prices. Since a comprehensive study of livestock numbers is not conducted annually this is only an educated guess. The project objective of reducing fecal coliform bacteria concentration by 70 percent is attainable. However, this is an area which will require intensified information and education to the landowner.

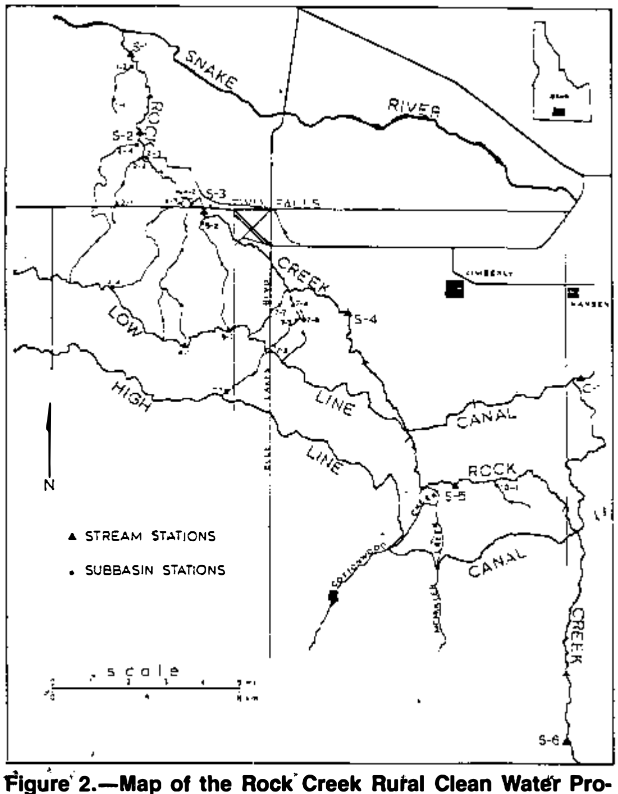

Figure 2.—Map of the Rock Creek Rural Clean Water Program study area, Twin Falls County, Idaho.

Pesticides and Other Toxins

Samples of game fish for pesticide analysis were collected in March 1982 at Rock Creek sites S-1 and S-6 (Martin and Bauer, 1982). Site S-6 is above the irrigation drainageways. Rainbow and brown trout were analyzed for pesticides to determine whether pesticide usage in the project has an adverse effect on trout populations and to assess whether they posed a possible hazard to anyone consuming the fish.

Four pesticides, or their analogs, were detected in the samples: DDT, PCB, toxaphene, and dieldrin. Minimum detection limits for these toxins are 0.001 mg/kg, which is equivalent to one part per million (ppm).

Residues in trout at both stations were low, and well below Food and Drug Administration (FDA) standards for human consumption. DDT averaged 0.106 ppm in rainbow trout near the mouth (S-1), and 0.012 ppm in rainbow trout above the project area (S-6). Large suckers at the mouth of Rock Creek contained the highest concentration of pesticide residue, but these concentrations were still well below the FDA standards.

Another sampling of game fish for pesticide analysis was conducted in March 1985. The results of those tests are pending.

It appears from this small sample that pesticide residues are not a problem in Rock Creek and will not interfere with the RCWP efforts to enhance the fishery. However, if drastic changes in tillage operations occur (see Program Changes, this paper) the need to continue pesticide monitoring must be considered.

Sediment Generation and Routing Model for Irrigation Return Flow

Studies of sediment transport in Rock Creek showed that no computer models of sediment routing could determine the impact of changes in quality of irrigation return flow from the Rock Creek watershed. Analysis of flow rate and sediment data indicated that 85 percent of the sediment transported in the stream is wash load (irrigation return flow sediment) and could not be modeled (Sterling, 1983). Analysis of sediment particle sizes, inflows, and deposition patterns in the lower reach of Rock Creek and application of transport models showed that irrigation return flow sediments are generally washed through the stream on an annual basis.

A furrow irrigation sediment yield model based upon stream power concepts was developed and tested (Brockway et al. 1985). The model, sensitive to furrow end slope and to furrow roughness and using actual runoff hydrographs, was able to predict annual sediment yields within 10 percent of measured yields. Driven by runoff hydrographs, the sediment yield model was linked to a kinematic-wave furrow irrigation model. The combined models can predict the annual sediment yield from a field in a watershed when given information concerning number of irrigations, set times, furrow stream sizes, slope, roughness, length, and infiltration.

Sediment retention treatment models were also developed (Brockway et al. 1985) to define potential sediment retention rates of the BMP's. According to these models, the sediment retention practice construction designs used by SCS have potential retention rates in excess of those required by the project guidelines. The vegetative filter strip model predicts a potential sediment removal efficiency based upon ideal management. The management of the filter strip will significantly influence the operational sediment removal efficiency. Whereas the filter model predicts efficiencies of 80 to 90 percent measured on ideally managed strips, normal farm management of filter strips will produce operational efficiencies of 50 percent.

The watershed sediment yield model estimates the average sediment yield at the field edges. The model does not account for sediment deposited in drains or on fields due to reuse of irrigation return flows. However, the model does adjust sediment yields to account for BMP's installed at field edge by using their sediment removal efficiency. BMP's the model takes into account include filter strips, sediment basins, I-slots, T-slots, minibasins, and buried pipe runoff control systems.

PROGRAM CHANGES

The sediment yield problem appears to be under control, relative to water quality in Rock Creek, especially with many more sediment retention BMP's planned for implementation. A logical question is: how long will the reduced sediment yield and improved water quality in Rock Creek last? Will landowners realize the usefulness of BMP's and continue to install and maintain them after contract obligations have expired, and without cost-share funds?

A study of irrigation return flow was carried out from 1976 through 1980 by USDA–Agricultural Research Service and the University of Idaho Agricultural Engineering Department, in conjunction with the Snake River Soil Conservation District, IDHW, Division of Environment, and U.S. EPA (Brockway et al. 1980). BMP's were developed for reducing sediment and nutrient concentrations in irrigation return flows, and these practices were applied to a small drain, the "LQ," which is adjacent to the Rock Creek RCWP project and discharges directly into the Snake River. Because of BMP implementation, the sediment discharged to the Snake River was reduced by 80 percent, from 10,000 tons per year in 1977 to 2,000 tons per year in 1979.

The 1983 post-project evaluation of the LQ Drain watershed indicated a significant improvement in water quality. However, there had been a reduction in water quality when compared to the end-of-project levels. The amount of sediment leaving the watershed in 1983 (5,500 tons) was 55 percent of 1977 (10,000 tons), but 275 percent of the 1980 (2,000 tons) end-of-project level. During the 1981 through 1983 period, governmental assistance was very low for BMP's, as were information and education efforts. As a result of no government assistance and a depressed farm economy, practice implementation was minimal and water quality in the LQ Drain is again declining.

With the LQ Drain project as an example, it is clear that steps are needed to ensure that Rock Creek will enjoy long-term benefits from the RCWP.

The original philosophy of the Rock Creek RCWP contended that improved water quality could be achieved by implementing BMP's that improved the irrigation system, for example concrete ditch and gated pipe, and BMP's that trapped end of furrow sediment yield, such as vegetative filter strips, sediment basins, and buried pipe runoff control systems. These BMP's would be supplemented by a strong information and education effort in irrigation water management, also a planned and contracted BMP. Monitoring data indicate that the program is achieving the main objective—sediment reduction in Rock Creek—and that the creek is gradually improving. However, these accomplishments are shortsighted, and, as was learned in the LQ Drain project, will probably be short-lived.

One of the problems with the original philosophy was that it did not adequately address erosion-control practices and problems associated with the continued reduction of crop yields where topsoil depth is at a critical point. Another problem that has come to light is that this philosophy is too expensive.

Economic analysis of the BMP implementation phase of the RCWP strongly suggests that emphasis on less costly field management practices will be necessary to ensure an economically justifiable project (Gum et al. 1984). The initial emphasis on structural irrigation and sediment retention practices interested farmers in participating, but the current need, as dictated by cost-to-benefit ratio, is to reemphasize irrigation water management and to initiate field management practices such as reduced tillage, minimum tillage, and crop residue. These types of practices (1) reduce farmer costs; (2) reduce in-furrow erosion, resulting in greater long-term benefits; (3) reduce end of furrow sediment yield more cost effectively; (4) provide increased protection of the resource base; and (5) have a high probability of continued farmer use after the project is completed and the contracts have expired.

At this stage we now recognize that improving irrigation systems and irrigation water management techniques, while important and effective in reducing erosion and subsequent sediment yield, does not technically and economically address the water quality problem in the best way possible. BMP's that will improve in-furrow erosion control must be incorporated into the Rock Creek RCWP.

This recognition was included in the 1984 Rock Creek RCWP Annual Report. A request to cost-share conservation tillage practices was made in the report. That request received full concurrence by the Local Coordinating Committee and State Coordinating Committee. The National Coordinating Committee has recently approved the conservation tillage BMP for cost-share under the Rock Creek RCWP.

SUMMARY

The Rock Creek Rural Clean Water Program has significantly reduced sediment loading into Rock Creek using a combination of sediment retention and irrigation improvement practices, including irrigation water management.

Participation has been higher than expected because of a successful information and education effort, cost-sharing, and the positive results of BMP's already used that stimulated further landowner interest. The project has approximately 11,400 ha (28,159 ac) identified as critically eroding or highly subject to erosion. The goal is to treat 75 percent, or 8,550 ha (21,119 ac), through a combination of BMP's carried out under long-term contracts. As of September 1984, 146 contracts planned to treat 7,092 ha (17,517 ac) were in effect, approximately 83 percent of the contracting goal. One year of contract preparation remains. Since the first contract was approved in October 1980, about 1,025 individual BMP's have been implemented, among them 17 sediment basins exceeding 765 m^3 (1,000 yd^3) each. Practices have been applied mostly on schedule, and even though some landowners are delaying implementation because of poor economic trends, BMP implementation has progressed well overall. Few requests for planning assistance are received. After only 4 years the Rock Creek RCWP has significantly helped meet targeted chemical parameters. As BMP implementation expands to influence and benefit more acres in the project area, the resultant reduced pollutant loads discharged from the subbasins should become even more pronounced. Rock Creek will be slow to establish stable long-term changes in its chemical and biological composition, but when the remaining sources of pollutants in irrigation return flows are subjected to the proposed level of BMP implementation, positive long-term improvement in the aquatic ecosystem should come about.

A tremendous challenge comes with the decision to implement conservation tillage on furrow irrigated cropland. Practically no information exists about conservation tillage practices under this type of irrigation, even though millions of acres are irrigated in this fashion in the western United States.

It is a challenge to the agricultural institutions to adapt a technology long in use in some regions, but in its infancy here. The service agencies—Soil Conservation Service, Agricultural Research Service and Cooperative Extension Service—face a challenge in communicating this new information to land users. But mostly the challenge is to the farming community, a community now struggling to improve its chances for survival that must now accept, develop, and implement new ideas more quickly than it ever has in the past. The RCWP, as an experimental program, has an opportunity to promote conservation tillage as a method of controlling in-furrow erosion. We hope to answer some important questions, and we hope to be able to apply the answers to more than just the Rock Creek RCWP.

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REGULATING NONPOINT SOURCES OF POLLUTION FROM TIMBER HARVESTING—A CASE HISTORY OF THE CALIFORNIA EXPERIENCE

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ABSTRACT

California possesses over 16,800,000 ha of forest land, making it one of America's top timber producing States. To meet the mandate of the 1972 Federal Water Pollution Control Act, section 208, the State of California has had to initiate significant institutional and regulatory changes to comply with this legislation. Regulation of forest practices in California on private timber lands involves a complex process of rule-making, mandatory timber harvesting permits prepared by State-licensed professional foresters, interdisciplinary review and approval of timber harvesting plans by the State's Department of Forestry, and ongoing enforcement inspections during the operational life of the plan. In addition, logging operators in the State must also be licensed, adding additional leverage for rule compliance during logging. This paper summarizes the history of the last 8 years involving the California State Board of Forestry and the California State Water Resources Control Board efforts to institute a silvicultural nonpoint source pollution control program.

INTRODUCTION

California's forest resources are among the most valuable in the Nation. For 20 years California has ranked as one of the top three States in annual harvested volume of forest products. Over 42 percent of the State, 16.8 million ha (42 million acres) is forest land, an area larger than 30 of the 50 States. The forest lands produce over 70 percent of the annual water yield, on which California's agricultural and urban economies depend. Eight million ha (20 million acres) of this forest land is in private ownership and is subject to regulation by State forest practice rules whenever harvested commercially.

The subject of timber harvesting regulation and its relationship to water quality and other environmental concerns has provoked heated political controversy in California for almost two decades. More than the usual animosity between the timber companies and environmentalists, fishing interests, and local communities reflects a basic disagreement abut how the State's forests are to be used. Because California probably epitomizes the growing conflict of values at an urban/forest interface (Vaux, 1982), California's handling of such political confrontations may inform other States facing forest/urban conflicts in the future.

The 1972 Federal Water Pollution Control Act (FWPCA) placed responsibility for water pollution control in forest management at the State level, with oversight and national administration by the U.S. Environmental Protection Agency. The FWPCA did not give EPA direct authority over control of pollution from nonpoint sources, but dictated that nonpoint sources of pollution had to meet State-developed water quality standards that were approved by EPA. These became known as Basin Plans (Gefrath, 1984).

Although the FWPCA was probably one of the most complicated measures ever passed by Congress, the writers correctly assessed that nonpoint sources had to be treated by modification or elimination of practices that caused pollution. These best management practices (BMP's) were to be favored over "end of pipe" remedies so common to point source treatments. As a result, under section 208, local governments were required to develop Areawide Waste Treatment Management Plans for both point and nonpoint sources of pollution. Also under this section, the governor of each State could require that agricultural, silvicultural, mining, and related nonpoint source activities become part of a State's control program. If the State assumed control of nonpoint source enforcement, any plan for control must include: ". . . processes to (i) identify, if appropriate, agriculturally and silviculturally related nonpoint sources of pollution, and (ii) set forth procedures and methods (including land use requirements) to control to the extent feasible such sources."

Since FWPCA was passed, California has had two agencies with an interest in regulating silviculturally related nonpoint sources, the State Water Resources Control Board and the Board of Forestry. California's 1967 Porter–Cologne Water Quality Control Act designated the Water Resources Control Board as the State's water pollution control agency for all purposes stated in the FWPCA. The Board of Forestry, on the other hand, was the forest practices rulemaking body, directing policy for the State's Department of Forestry, the enforcement agency for forest practice regulation. In 1976, sensing that a battle over regulatory turf would be best avoided, Governor Edmund Brown Jr. assigned the Federal–State coordination and contractual duties to the Water Resources Control Board, but allowed for that agency to subcontract to the Board of Forestry for development of a set of BMP's for silvicultural operations. The interagency agreement called for the Board of Forestry to review and revise rules relating to watercourses and erosion control, erosion hazard rating, and silvicultural and cutting methods; to provide for increased public notice of harvesting operations; and to formalize an interdisciplinary review team procedure for timber harvesting permits. It was the State's intent to eventually certify the Board of Forestry as the agency designated to carry out the mandates of section 208 on private timber lands.

In early 1979, the Board of Forestry set up a committee of its own and Department of Forestry personnel, industry and public agency foresters; other land use specialists, environmental organization representatives, and the general public to study forest practices as they related to water quality. They investigated whether the structure of mandatory timber harvesting permits and licensing professional foresters and loggers, along with an aggressive enforcement program would provide an adequate framework for a BMP program. They also examined the changes required to correct potential deficiencies. This report was submitted in its final form to the Water Resources Control Board in October 1983. In March 1984, after lengthy hearings and much heated testimony, the Water Resources Control Board granted certification to the Board of Forestry for a limited term, 4 years. Because the Board of Forestry study presented new rules and procedures, the Water Resources Control Board made certification contingent upon the development of a Monitoring and Assessment Program to evaluate the Board of Forestry program. At the end of the 4-year term, further hearings will determine if an unlimited time certification will be granted.

THE CALIFORNIA PROGRAM—OVERVIEW

The California BMP program for forestry relies on more than just rules. Even though the rules are acknowledged by most authorities as the toughest forest practices laws in the United States, California's program involves an integrated process involving legislation, administrative regulations, licensing of professional foresters and timber operators, and an active enforcement program. California chose an integrated process for three reasons:

Timber Harvesting Is Very Site-Specific

Forested terrain in California varies greatly in physical features, site quality, vegetative species, and climatic factors. Ownership objectives and past logging history serve to compound these variations, making it very difficult to set narrowly prescribed standards for performance, as might be common in regulating point sources.

Public concerns over timber harvesting are usually greater in more heavily populated forest areas. Considerations such as traffic, noise, and timing of logging become important, in addition to questions of water quality.

In response to the adverse environmental effects of timber harvesting, many mitigation measures are possible. However, practices that work in one place may not work elsewhere, may not be needed, or may even cause damage.

In view of the wide variety of conditions, the Board of Forestry chose to adopt general, flexible rules and then find a process to make them specific. This is an extremely important point and will be elaborated upon later in this paper.

A Mixture of State Laws Influence Forest Practices

The Board of Forestry operates under the Forest Practices Act, the Professional Foresters Law, the California Environmental Quality Act (CEQA), the Coastal Act (a coastal zoning law), the Wild and Scenic Rivers Act, and a variety of provisions in the State's Fish and Game Code, the Water Code and the Government Code.

The Professional Foresters Law and a strong new Forest Practices Act went into effect in 1972–73. A court decision in 1975 held that provisions of CEQA applied to timber harvesting. Ultimately the concept of functional equivalency under CEQA was developed. Board of Forestry rules and procedures were changed and certified as functionally equivalent to the environment impact review procedures under CEQA for other types of projects. Multidisciplinary review of proposed harvesting operations were included.

Until 1978, the director of the Department of Forestry could require the necessary mitigation measures under CEQA even if such measures were not spelled out in the Forest Practice Rules. The Legislature in 1978 mandated that the Board of Forestry include standards in its rules for the director to exercise discretion in their application. This mandate changed the types of general rules that could be used by the Board of Forestry and led to more emphasis on procedures and the timber harvest plan review process to make the rules specific.

Maximum Flexibility in the Field Was Needed

California has the strongest law to license and discipline foresters in the United States. Foresters working for both the Department of Forestry and private timber companies and landowners are usually licensed or in training for licensing. Timber operators must also be licensed.

To harvest timber commercially (for sale or exchange) in California requires that the registered professional forester prepare a timber harvest plan. This document goes through an interdisciplinary review process and eventually contains *specific enforceable conditions* to protect the environment. These conditions interpret and make the Forest Practice Rules specific.

The Board of Forestry has adopted the philosophic premise that rules will be written rather generally and be made specific in the timber harvest plan. This is very similar to the practice of the U.S. Forest Service to adopt very general statements in policy and to make them specific in technical manuals and handbooks. Recent rulemaking by the Board of Forestry has heavily emphasized registered professional foresters. Less reliance is placed on prescriptive standards in rules to control loggers and more reliance is placed on the timber harvest plan.

THE CALIFORNIA PROGRAM IN DETAIL

The Forest Practice Act

This act requires the Board of Forestry to adopt rules to assure the continuous growing and harvesting of commercial tree species and to protect soil, fish, and wildlife resources. Board of Forestry rules must deal with soil erosion, water quality, watershed control, flood control, and the control of timber operations that will adversely affect the uses of waters in the State.

Before harvesting, timber owners must have obtained a timber harvest permit prepared by a registered professional forester and approved by the director of the Department of Forestry. It is a *mandatory permit,* analogous to a building permit, and it is a criminal offense in California to commercially harvest timber without one. Proposed permits are noticed publicly and reviewed by an interdisiplinary review team that may recommend acceptance of the plan with or without modification. It may also recommend rejection if suggested additional mitigation measures meeting the standards set in the rules are not incorporated by the submitting registered professional forester.

The Timber Harvest Plan Process

Figure 1 illustrates the complete timber harvest permit process in California. The process is broken up into three periods: the filing period; the preharvest inspection period, which is not compulsory where no environmental questions exist; and the review period, when the review team determines if additional mitigation measures are needed.

Note that the time periods listed are maximums. The longest time it would take a timber harvest permit to pass through this process is 35 days. A longer time may be involved if the permit submitter and the Department of Forestry agree to an extension, as in circumstances involving lengthy negotiations on mitigation measures. In practice, the average permit is processed in about 20

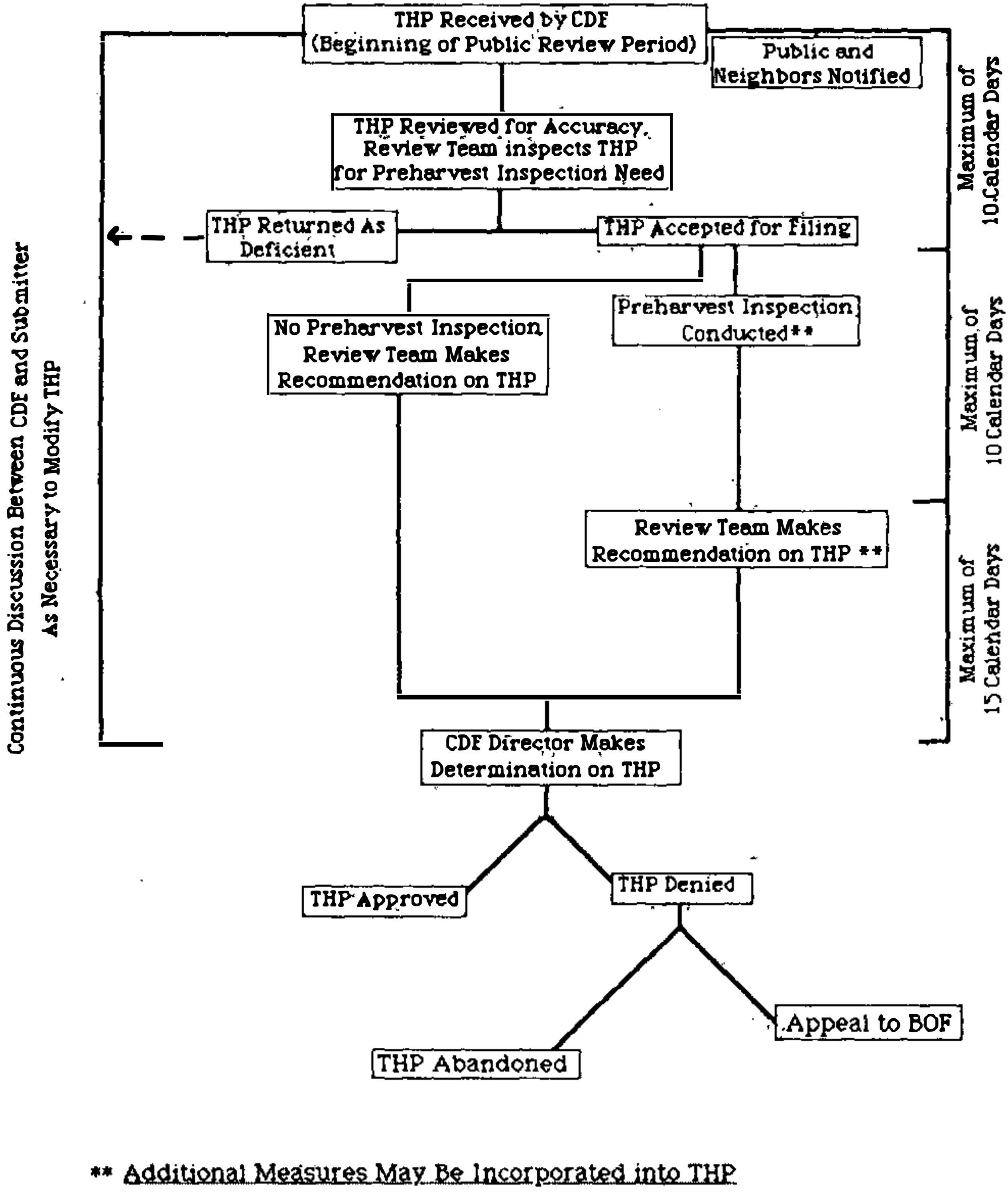

Figure 1.—California's timber harvesting plan review process.

days, and no less than 10 days; so that public comment can be heard, even on a simple, very remote plan.

For the State as a whole, an average of over 1,400 permits per year has been processed in the recent past. This is down from as high as 1,900 plans during the late 1970's. Review teams work at each of the five Department of Forestry regional offices. However, a great majority of the permits, both in numbers and volume harvested, occur in the northern half of the State.

If a permit is denied by the Department Director, the submitter may appeal to the Board of Forestry. At present, no other party may appeal the issuance or denial of a timber harvest permit.

Enforcement

As has been mentioned previously, Board of Forestry rules are enforced by the Department of Forestry. The Forest Practice Enforcement Process is shown in Figure 2. The Department has many legal enforcement tools as shown in Table 1. Obviously, the Department inspectors attempt to use persuasion and less severe tools to obtain compli-

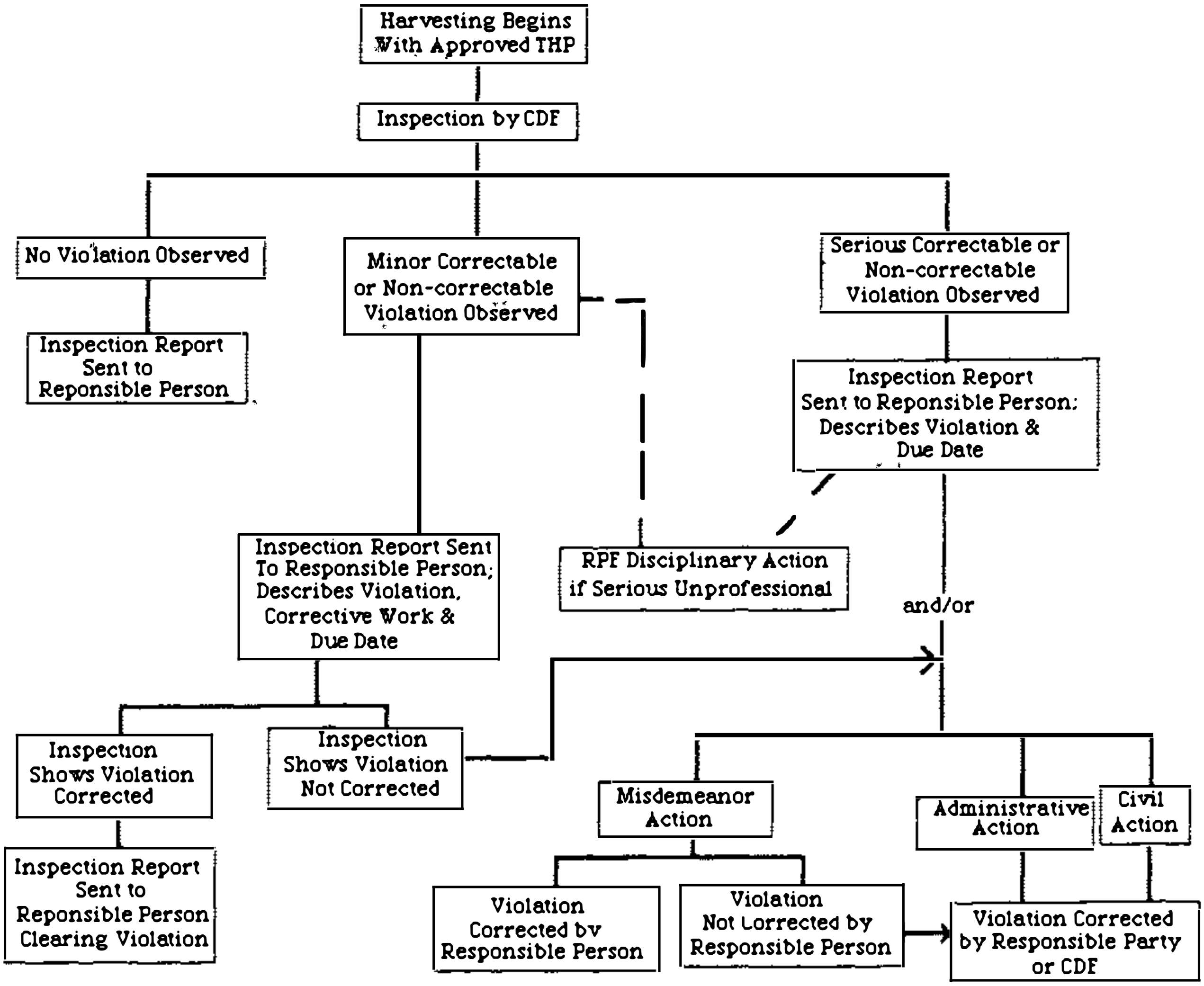

Figure 2.—California's forest practice enforcement process.

Table 1.—Forest Practice Enforcement Actions and Possible Resolutions.

Actions available	Possible resolution
1. Warnings	Via inspection reports, verbally; and/or administrative letters
2. Notice of intent to take corrective action	Violation corrected by responsible person; violation corrected by CDF
3. Stop work orders	Violation corrected—operations continue; agreement entered into for continuance of operations; injunctive process started
4. Injunctive process	Temporary restraining orders; preliminary injunctions; permanent injunctions; court ordered correction; stipulated agreements
5. Misdemeanor action	Fine; probation; incarceration; dismissal
6. Timber operator license action	Warning; suspension; revocation; dismissal
7. RPF disciplinary actions	Warnings; letters of reprimand, suspension; revocation

ance with the rules and conditions in the timber harvest plan, such as warnings, before resorting to judicial and misdemeanor remedies.

Continuous Rule Review

As section 208 anticipated, the Board of Forestry continuously reviews its rules and institutional procedures. Consultation with Federal and other State agencies is mandatory. This is important because no set of rules and procedures is perfect. There must be ways to incorporate improvements, experience, changing technology, and evolving institutional needs. From the beginning of its involvement with the FWPCA, the Board of Forestry has believed that providing for such changes is implicit in the term best management practices.

OUTLOOK FOR THE FUTURE

California is one of America's leading timber States. Yet it was probably the last major timber State to develop a 208 plan for managing nonpoint sources of pollution from silvicultural operations. It based its program around a previously developed regulation program rather than around voluntary or educational programs as in other States. As a result, the Board of Forestry estimates that its program increased logging costs by up to $13 per thousand board feet. When compared to stumpage prices ranging from about $100 to $150 per thousand on a statewide average, this is not an inconsequential cost.

The Board has established a system of general water quality and environmental protection, leaving its field personnel considerable flexibility at specific sites. This flexibility and reliance on a process has made California water quality personnel uneasy, especially since their predominant experience is in regulating point sources of pollution. This difference in philosophies was largely responsible for the delay in certifying California's silvicultural BMP program. In fact, the story is not yet complete as the results of the 4-year Monitoring and Assessment Program will not be available until after 1989, at the earliest.

Appropriately this paper ends with the unfinished California Experience. In the field of water quality regulation, the final chapter may never be written. However, for students of this field, California's experiences will undoubtedly give many examples of what to do and what not to do. Many States are experiencing, or are about to experience, the urban/forest interface problem similar to California's. Water quality–forest harvesting concerns will only be the "point man" for many other heated concerns. Forestry and water quality regulators will need to work together very closely to avoid expensive and highly divisive tests of political will.

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AGRICULTURAL NONPOINT SOURCE STUDIES IN SOUTHEASTERN WATERSHEDS: FIELD MONITORING AND FARMER SURVEYS

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ABSTRACT

Annual nitrogen, phosphorus and sediment loadings for 2 to 4 years of field sampling in three geographic regions of North Carolina are presented. Predictive equations developed to expand the concentration data for use with the more complete flow record to calculate annual loading rates are described. Comparisons between the five Coastal Plain, six Piedmont, and one mountain watershed, and with literature values are made. Producer surveys were conducted 4 years for the Coastal Plain study and 2 years for the Mountain study. Questions were designed to evaluate farmer awareness of technical and cost-sharing assistance available. Information on attitudes concerning the need and adoption of BMP's to control nonpoint sources at the beginning and end of the study period was also collected. Results show the need for and challenges that exist for producer education and motivation to implement and maintain appropriate recommendations. Techniques are recommended for evaluating nonpoint source control program effectiveness or water quality changes over time and space based on experiences with judgmental and statistical grab and instrumental sampling, modeling techniques, and plot versus watershed studies.

INTRODUCTION

Studies have been conducted in North Carolina since 1975 to determine techniques for measuring areawide water quality and to evaluate the effectiveness of agricultural nonpoint source control programs. Resulting data add to state-of-the-art values for flow and concentrations and thus annual loading rates or yields. Such data sets also provide a better technical base for estimating areawide water quality and nonpoint source impacts at a fraction of the time and cost of extensive field monitoring programs.

Results for measured average total flow and measured average constituent concentrations are shown in Table 1; total nitrogen (TN), total phosphorus (TP), and chemical oxygen demand (COD) yields in Table 2. Data from the project, Probability Sampling to Measure Pollution From Rural Land Runoff (Humenik et al. 1980), are noted as Chowan River I in these tables. Data listed for Chowan River II, Coastal Plain, and Piedmont were derived from a series of studies to evaluate strategies for reducing agricultural nonpoint source impacts (Humenik et al. 1983; Humenik and Foreman, 1984). Data for the Mountain area were from similar watershed studies conducted by North Carolina State University (NCSU) workers (Kilmer et al. 1974), a cooperative NCSU–Tennessee Valley Authority (Tenn. Valley Auth. 1963), and the Dunn Creek Agricultural Nonpoint Source Control Project (Humenik et al. 1985).

Flow

The literature state-of-the-art value of 0.8-1.2 $ft^3/sec/mi^2$ sets the basis for evaluating flows presented in Table 1. The simple numerical average shown for the measured average total flow in each region, as well as for all regions, yields a surprisingly similar value of about 1.0 $ft^3/sec/mi^2$. Thus good confirmation exists between state-of-the-art and measured average total flow for very different geoclimatic regions ranging from the Costal Plains to the Blue Ridge Mountains in North Carolina.

Constituent Concentrations

A general gradient is apparent in the average constituent concentrations listed in Table 1, with the highest ranges being for Mountain, intermediate for Piedmont, and lowest for the Coastal Plain watersheds, which include the Chowan River. Similar ranges are noted for total Kjedahl nitrogen (TKN) and nitrite-nitrate ($NO_{2\text{-}3}$). Thus the level of average TN, TP, and COD concentrations seem to be related to land type, stream gradient, and potential runoff transport. The average nitrate values range from 2.09 for the Piedmont to 0.74 for the Coastal Plain and 0.63 mg/L for the Chowan River in spite of the higher infiltration capacity and ground water inputs in the Coastal Plains. Denitrification in the high organic and saturated Coastal Plain and Chowan River watershed soils can contribute to the lower nitrate levels recorded for this area.

These data can be compared with values from a national estimate of nonpoint source-related nitrogen and phosphorus concentrations presented in the U.S. Environmental Protection Agency report, Nonpoint Source–Stream Nutrient Level Relationships: A Nationwide Study (Omernik, 1977); these concentrations are also listed in Table 1. While some of the nutrient concentrations in streams listed by the nationwide survey are similar to the arithmetic average of values listed in Table 1, such as about 1.0–1.5 mg/L total nitrogen in the Coastal Plains area, other survey versus measured values are much different, such as TN in the Piedmont area, 0.7–1.4 versus 4.02 mg/L; TP in the Coastal Plains area, 0.051–0.7 versus 0.18–0.21 mg/L; and TP for the Piedmont, 0.31–0.07 versus 0.59 mg/L.

Additionally, the gradient in nitrogen and phosphorus concentrations measured for North Carolina watersheds as listed in Table 1 is not as apparent in the concentrations shown in the topographical type mapping for North Carolina (Omernik, 1977). Nevertheless, such estimates of average constituent concentrations provide helpful information that can be refined by local studies to provide increasing reliable state-of-the-art values to evaluate ambient water quality and the effects of nonpoint sources on receiving waters.

Annual Yields

Annual yields or loadings in kg/ha/yr can be calculated based upon flow and concentration data. It would be most desirable to develop good relationships between flow and concentration for a given sampling station to use with the more easily obtained flow data from stage recorders or U.S. Geological Survey type records to calculate constituent loadings. However, very poor relationships between concentration and flow have been recorded at watersheds studied in North Carolina and these are corroborated in

Table 1.—Measured average nitrogen, phosphorus, chemical oxygen demand and flow for North Carolina watersheds.

Watershed	Acres	Year	TP	TKN	NO_{2-3}	TN	COD	Flow
			mg/l					$ft^3/sec/mi^2$
			MOUNTAINS					
Western N.C.—1	4.67	68–72	0.08		1.2	1.6		0.57
Western N.C.—2	3.65	68–72	0.1		3.9	4.6		0.75
Dunn Creek	614		0.85	4.66	1.73	6.53	204	1.0
Parker Branch								0.70
Nationwide Study (Omernik, 1977)			0.03–0.07			0.5–1.4		
			PIEDMONT					
Gourdvine Creek	5,621	79	0.72	1.76	2.4	4.17	163	1.5
		80	0.45	1.27	2.89	4.17	45.7	0.85
		81	0.77	2.57	4.49	7.22	132	0.29
		82	1.6	4.17	5.61	9.62	202	1.3
Lanes Creek	3,727	79	0.55	2.08	1.48	3.53	57.7	1.42
		80	0.32	1.49	0.85	2.4	38.6	0.99
		81	0.71	2.73	1.76	4.49	64.8	0.31
		82	0.37	1.44	1.09	2.57	41.4	1.18
Wicker Branch	3,087	79	0.4	1.4	0.85	2.24	74.4	1.3
		80	0.27	0.98	0.96	1.92	52.4	1.16
		81	0.58	1.92	1.92	4.0	112	0.33
		82	0.37	1.22	0.79	1.92	49.9	1.1
Arithmetic Average			0.59	1.92	2.09	4.02	132	0.98
Nationwide Study (Omernik, 1977)			0.31–0.10			0.7–1.4		
			COASTAL PLAIN					
Beaverdam Creek		79	0.03	0.48	0.48	0.96	42.8	1.36
		80	0.04	0.32	0.53	0.85	34.8	1.14
		81	0.10	0.48	0.74	1.28	73.9	0.79
		82	0.19	1.36	0.55	1.92	151	1.02
Daily's Creek		79	0.27	0.77	1.6	2.4		1.15
		80	0.32	1.25	2.08	3.37		1.19
Bear Creek		79	0.24	0.66	0.42	1.07	30.6	1.53
		80	0.16	0.66	0.66	1.31	32.2	0.94
		81	0.26	0.82	0.18	0.99	44.6	0.55
		82	0.16	0.53	0.14	0.67	26.6	1.17
			CHOWAN RIVER I					
Forested Piedmont	(4 sites)	75–76	0.12	1.12	0.04	1.16	23.5	0.93
Agricultural Piedmont	(3 sites)	75–76	0.10	1.0	0.11	1.11	17.8	1.14
Well-drained Coastal Plain	(4 sites)	75–76	0.12	1.10	0.75	1.85	26.1	1.57
Poorly-drained Coastal Plain	(4 sites)	75–76	0.22	1.18	0.53	1.71	26.6	0.31
			CHOWAN RIVER II					
Well-drained agricultural								
Bells Branch	498	79–80	0.86	0.82	2.04	3.1		0.98
		81–82	0.08	0.65	2.8	3.5		0.70
Cypress Creek	4,590	79–80	0.06	0.43	0.16	0.61		1.02
		80–81	0.12	0.64	0.04	0.69		0.46
		81–82	0.08	2.45	0.18	0.64		0.75
Panther Swamp	6,953	79–80	0.16	0.65	0.52	1.19		1.76
Poorly-drained agricultural								
Cutawhiskie Lateral	752	81–82	0.55	1.82	0.27	2.1		1.83
Poorly-drained forested								
Big Woods	799	81–82	0.06	0.5	0.08	0.61		0.67
Arithmetic average			0.2	0.9	0.68	1.5		1.04
Nationwide Study (Omernik, 1977)			0.051–0.07		0.09–1.1			
Arithmetic Average for all flow data								0.99

Table 2.—Nitrogen, phosphorus and COD yields for North Carolina watersheds.

Watershed	Acres	Time	N kg/ha/yr	P kg/ha/yr	COD kg/ha/yr
		MOUNTAINS			
Western N.C.—1	4.67	1968–1972	3.2	0.15	
Western N.C.—2	3.65	1968–1972	12.1	0.27	
Dunn Creek	614	5/81–6/83	22.4	6.4	703
		PIEDMONT			
Gourdvine Creek	5,621	1979	21.4	3.7	844
		1980	12.3	1.3	133
		1981	7.0	0.75	130
		1982	44.4	7.5	926
Lanes Creek	3,727	1979	17.6	2.7	282
		1980	8.0	1.1	131
		1981	4.8	0.74	68
		1982	10.3	1.5	168
Wicker Branch	3,087	1979	10	1.8	334
		1980	7.8	1.1	209
		1981	4.5	0.65	127
		1982	7.6	1.4	189
		COASTAL PLAIN			
Beaverdam Creek	2,855	1979	4.5	0.12	200
		1980	3.4	0.16	137
		1981	3.5	0.25	202
Daily's Creek	2,568	1979	9.4	1.1	165
		1980	14.0	1.3	152
Bear Creek	2,986	1979	5.7	1.2	164
		1980	4.3	0.50	104
		1981	1.9	0.50	85
		1982	2.7	0.67	108
		CHOWAN RIVER I			
Forested Piedmont (4 sites)		6/75–11/76	3.8	0.39	76
Agricultural Piedmont (3 sites)		6/75–11/76	4.3	0.38	69
Well-drained Coastal Plain (4 sites)		6/75–11/76	8.6	0.56	122
Poorly-drained Coastal Plain (4 sites)		6/75–11/76	1.8	0.22	27
Well-drained Coastal Plain					
W-3	4,003	6/75–11/76	6.4	0.71	
W-4	124	6/75–11/76	5.1	0.17	
W-8	2,125	6/75–11/76	3.6	0.34	
W-10	4,077	6/75–11/76	3.0	0.25	
Poorly-drained Coastal Plain					
P-8	2,891	6/75–11/76	3.4	0.26	
P-10	2,397	6/75–11/76	2.3	0.31	
P-11	3,138	6/75–11/76	4.1	0.22	
P-13	24,339	6/75–11/76	4.9	0.38	
		CHOWAN RIVER II			
Well-drained Agricultural					
Bells Branch	498	7/79–6/80	10.5	2.9	
		10/81–9/82	8.4	0.20	
Cypress Creek	4,590	7/79–6/80	2.1	0.21	
		10/80–9/81	1.18	0.19	
		10/81–9/82	1.7	0.20	
Panther Swamp	6,953	7/79–6/80	7.2	0.95	
Poorly-drained Agricultural					
Cutawhiskie Lateral	752	10/81–9/82	13.6	3.57	
Poorly-drained Forested					
Big Woods	799	10/81–9/82	1.3	0.13	

the literature. Therefore, predictive equations were developed to relate concentration to flow so that concentrations could be generated for use with the more complete flow record to calculate instantaneous constituent flux and then annual loading rates.

The methods for computing short- and long-term sediment yield given in the Field Manual for Research and Agricultural Hydrology and the American Society of Civil Engineers Sediment Engineering Manual were found to provide suitable predictive tools for determining constituent yields. These procedures used to calculate constituent flux on an instantaneous basis are based on the straight line relationship resulting from a log-log plot of instantaneous flux versus flow.

The coefficient of determination (R^2) can be determined to indicate the closeness of fit or reliability of the straight line equation on the log–log plot to predict constituent concentration from flow data. The standard error of the estimate for regression coefficients can also be determined, allowing designation of statistical significance.

Predictive regression equations can be developed for total flow, stormflow, or baseflow. If the stormflow and baseflow models are better (higher R^2, better fit from examination of residuals), those equations should be used for baseflow and stormflow conditions rather than using an equation for total flow. Water quality samples can be grouped by season for the total data set or by season for each year in an effort to obtain equations with better fit or a higher coefficient of determination (R^2). As equations are developed for more specific flow regimes and time periods, the R^2 factor should increase, thus justifying using more equations with a higher level of accuracy for developing relationships between flow and concentration and predicting instantaneous loads. Computer programs or other modeling techniques can be used to calculate the area under the curve formed by plotting instantaneous loads in kg/hr versus time to determine loads or yields over time in kg (Humenik et al. 1983, 1985).

The TN, TP, and COD loads in kg/ha/yr calculated according to this procedure are listed in Table 2. Such loading values are used for water quality planning and evaluation by State government in North Carolina with the nitrogen loading rate being 6.3 kg/ha/yr for the Coastal Plain and the Piedmont, while the total phosphorus loading is 1.1 kg/ha/yr for the Piedmont and 0.55 kg/ha/yr for the Coastal Plain (N.C. Dep. Nat. Resour. Comm. Develop. 1982, 1983). Such data as listed in Table 2 serve to verify or update and refine such areawide loading guidelines for nonpoint source control water quality management.

Producer Surveys

A producer and field practice survey was taken each winter from 1979 to 1982 to cover the previous crop year, and a project evaluation survey was conducted for the Chowan River II study. A similar survey was conducted in conjunction with the Dunn Creek nonpoint source technical assistance and evaluation watershed study. Selected portions of these surveys are shown in Tables 3 and 4.

Results of the Coastal Plain watershed survey, which covered 95 percent of the 12,793 acres in study watersheds (Humenik et al. 1983), revealed that the level of soil testing remained fairly high, between 75 and 80 percent, during the study period. However, an evaluation of fertilization data shows that in 1981, 14 tons of excess nitrogen and 37 tons of excess phosphorus were applied to 4,600 acres of corn, peanuts, and soybeans. The nitrogen and phosphorus value of this unnecessary fertilizer was about $23,000. One suggested reason for this overapplication is that chemical fertilizer dealers do not offer customized blends for different fertilization needs.

The survey revealed a rapid growth in broilers, with over 100,000 in the study watersheds, and also that of the several hundred swine, some 25 to 100 had stream access at various periods throughout the year. None of the producers surveyed indicated having animal waste tested for nutrient content, although survey results showed fertilizer rates were reduced to account for manure application. An inventory of animal production and waste management in the five counties bordering the Chowan River in North Carolina indicated that the broiler litter produced in 1980 had a value of $2.7 million. Costs used were 25¢/lb nitrogen and 22¢/lb phosphorus for an annual value of $1.5 million for nitrogen and $1.14 million for phosphorus. The overall value would be even higher if potassium had been considered. Therefore, important animal waste best management practices (BMP's) included educating producers on the fertilizer and economic value of broiler litter and developing easy and effective techniques for land application.

The factors mentioned as having the most effect in promoting the use of conservation practices were, in order of importance: (1) cost-sharing, (2) technical assistance, and (3) tax credits or incentives. Leasing agreements were often cited as an important factor restricting BMP implementation. It was disappointing to note that only about 30 percent reported a conservation plan prepared by the Soil Conservation Service, and only 34 percent of the producers were interested in trying no-till farming. Participation in the integrated pest management (IPM) program dropped from 48 percent in 1980 to 30 percent in 1982.

Questions gleaned from the Dunn Creek mountain watershed producer survey (Humenik et al. 1985) listed in Table 4 indicated a good awareness of soil and water conservation programs. However, it is interesting to note the varying and changing opinions on conservation problems and needs as well as producers' willingness to implement BMP's to control agricultural nonpoint sources. Responses from the approximately 12 producers in this 614-acre watershed indicated that very few producers had prepared a farm conservation plan, were interested in trying no-till equipment, or believed they had nonpoint source problems. On the positive side, it should be noted that results from the second survey year indicated more producers would be willing to carry out conservation practices, participation in IPM increased, and virtually everyone became familiar with no-till equipment.

Results of these surveys reveal some of the needs and challenges that exist for producer education, assistance, and motivation. Well-recognized and easy to implement agricultural practices such as erosion control, soil testing and good fertilizer management practices must continually be stressed as very important and cost-effective BMP's. Increased emphasis must continually be placed on animal waste management programs that use waste testing, soil testing, and proper application rates to minimize overfertilization. It should be stressed that these practices benefit both production agriculture and water quality.

A $2.2 million agricultural cost-share program was approved by the North Carolina legislature for 1984–1985 to finance nonpoint source controls for nutrient sensitive watersheds. Farmers in parts of 16 counties can receive 75 percent average cost-share for approved BMP's and animal waste management systems up to a maximum of $15,000 per year to each applicant. Both annual and 3-year agreements are available with requirements to maintain and continue practices for a specified period. The goal of this State funded program is to assist farmers in reducing the input of sediment, nutrients, animal wastes,

Table 3.—Coastal plain watershed producer survey results.

QUESTIONS

1. Which of the following would have the most effect in getting you to use good conservation and management practices?

First number is importance rank: 1—most important; 2—2nd in importance, 3—3rd in importance; other number is respondents. Not all producers assigned a 1, 2, 3 importance rank to questions resulting in differing number of respondents.

Technical Assistance	1/21	2/13	3/14
Cost-Sharing	1/37	2/23	3/2
Educational Activities: (such as on-farm tours, economic data on benefits, informational literature)	1/2	2/3	3/13
Advice of neighbor	1/0	2/1	3/4
Tax credit or incentive	1/6	2/25	3/9
Lease agreement (for those renting or leasing)	1/1	2/4	3/20

2. Who should be responsible for controlling the agricultural pollution problem (soil erosion, fertilizer loss, animal waste runoff)?

	No. of respondents	%
Individual Landowner	36	56
Local Government	2	3
Local Soil & Water Conservation District	8	12
State Government	0	0
Federal Government	6	9
Don't know	14	20

3. Who should bear the costs of practices which *reduce* erosion, fertilizer loss and other forms of agricultural pollution?

	No. of Respondents		Combination Responses
Individual Landowner	6	Individual Landowner and Federal Government	31
Local Government	2	Individual Landowner and State Government	3
State Government	2	Individual Landowner and State and Federal Governments	2
Federal Government	15	State and Federal Governments	1
Don't Know	3	All 3 Governments	1

Table 4.—Dunn Creek Mountain Watershed Producer Survey results.

	1981		1982	
	Yes	No	Yes	No
1. Are you aware of the technical assistance by the Soil and Water Conservation District?	8	3	10	2
2. Do you have a farm conservation plan prepared by the District?	0	11	4	8
3. Would you like to have one developed?	1	10	1	7
4. Would you be willing to carry out conservation practices developed with the assistance of the District?	3	8	11	1
5. Do you think you have conservation problems—erosion, stream siltation, fertilizer loss, etc.?	0	11	0	12
6. Do you participate in an Integrated Pest Management Program?	3	8	9	3
7. Are you aware of the availability of no-till equipment?	4	7	11	1
8. Are you interested in trying no-till equipment?	2	9	1	11
9. Are you familiar with ASCS cost-sharing practices?	5	6	11	1
10. Have you ever participated in ASCS programs?	4	7		
11. Did you use any conservation practices this year?			4	8

and pesticides into nutrient sensitive waters by increasing production efficiency and on-farm management.

Monitoring Programs

The goal of many field monitoring programs is to determine specific relationships between BMP systems installed and resulting water qualtiy changes. However, the work and resources required to accurately account for all conservation practices on a watershed and procure a total record of stream flow and associated constituent concentrations are generally grossly underestimated. Even if normal hydrologic conditions existed, most studies do not run long enough to detect these changes. Even more importantly, background water quality generally overwhelms changes that result from BMP implementation. The results of these and similar studies (Atkins, 1984) emphasize that BMP performance may be more cost-effectively determined by monitoring individual practices, fields, or farms, and not large watersheds. Too many variables and uncontrolled factors make it very difficult and expensive, if not impossible, to establish cause and effect relationships and document statistically significant water quality changes on a watershed basis.

Monitoring programs can provide good estimates of concentrations and yields for a particular site during the evaluation period. This data can be expanded over space if a statistically-based sampling program is developed to expand data to the whole sampling universe. The only way to expand monitoring data over time is to employ a conjunctive modeling effort. Actual field monitoring serves as the best basis for obtaining rate coefficients and other in-stream data required for modeling. Monitoring problems in obtaining a complete flow record and sufficient constituent samplings can be alleviated by developing predictive equations or models to relate concentration to flow on an instantaneous basis and then to annual yields. Coordinated monitoring and modeling programs ranging from simplistic loading analyses to detailed evaluations over time and space provide added tools for assessing BMP effectiveness.

Increased emphasis has to be directed to watershed characteristics in determining annual yields and evaluating reasons for high or low loading rates. The state-of-the-art is developing to the point that general yield estimate ranges can be made on the basis of watershed characteristics with primary emphasis on agricultural activities, soil types, watershed characteristics, and geoclimatic conditions. The systems approach should be taken to evaluate watershed loading rates and in-stream concentrations by conjunctive use of watershed characterization data, monitoring programs, and modeling techniques, depending upon the type of data required and the time and resources available. A very important conjunctive judgment is whether desired information is truly worth the cost in terms of time and resources—and whether the required level of precision can be obtained.

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VERMONT'S LAPLATTE RIVER WATERSHED PROJECT: LESSONS LEARNED

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ABSTRACT

In 1979, the LaPlatte River Watershed became the first land treatment only P.L. 83-566 project. The purpose of the project was to reduce the runoff of agricultural nonpoint source pollutants into Shelburne Bay of Lake Champlain. Being the first project of its kind, there were few established guidelines to follow for either planning or implementation. As the program evolved, its strengths and weaknesses have become more obvious. These lessons resulted in improvements for the ongoing project as well as for new projects. The LaPlatte River Watershed program is described. Both the watershed treatment project and the water quality monitoring and analysis program are discussed. Recommendations for the planning, implementing, and monitoring of similar programs are presented.

BACKGROUND

In the early 1970's, Shelburne Bay of Lake Champlain began showing signs of culturally accelerated eutrophication and excessive sedimentation. The Vermont Agency of Environmental Conservation determined that phosphorus from three municipal wastewater treatment facilities, as well as from nonpoint sources, was the primary nutrient responsible for the eutrophication. The LaPlatte River contributed as much as 63 percent of the nonpoint source phosphorus and virtually all of the agricultural nonpoint source pollutants to the bay. To improve the bay's water quality, a reduction in pollutants from point sources would have to be accompanied by a similar reduction in pollutants from nonpoint sources (Vt. Agency Environ. Conserv. 1977).

Vermont made the Shelburne Bay drainage basin one of its top priorities for agricultural nonpoint source pollution control (Vt. Agency Environ. Conserv. 1978). An accelerated program of cropland and streambank erosion control and proper animal waste management was prescribed for the LaPlatte River Watershed. (Soil Conserv. Serv. 1978; Vt. Agency Environ. Conserv. 1978).

Such a program was available through the Watershed Protection and Flood Prevention Act, as amended (P.L. 83-566). Enacted into law in 1954 and administered by the USDA Soil Conservation Service (SCS), P.L. 83-566 traditionally has been used for flood prevention. Though flood prevention projects often included watershed protection, a project had never been authorized solely for watershed protection. SCS began considering such projects in the mid 1970's because of national water quality concerns identified by the U.S. Environmental Protection Agency (Gallo, 1985).

The LaPlatte River P.L. 83-566 Watershed project was approved for planning in 1978. During planning, the project sponsors and SCS recognized the need to evaluate the effectiveness of this project in improving water quality. Therefore, they incorporated a Water Quality Monitoring and Analysis plan. The watershed protection and monitoring project, authorized for implementation in 1979, was the first of its kind in the Nation.

PROJECT SETTING

The LaPlatte River Watershed is located in Chittenden County, Vermont, just south of the city of Burlington. This 13,815-ha (34,100-acre) watershed drains westward into Lake Champlain's Shelburne Bay (Fig. 1).

The eastern headwaters region is in the Green Mountain foothills. This area represents about 20 percent of the watershed and is dominated by steep slopes, glacial till soils, and forests. The remainder of the watershed is primarily in the Champlain lowlands, where terrain ranges from rolling to almost flat; soils are lacustrine sands, silts and clays, and agriculture predominates (Cassell and Meals, 1981).

Overall land use is about 50 percent agricultural, 40 percent woodland, and 8 percent residential. About 60 active farms are in the watershed. Dairy farming dominates, with herds averaging 120 head. Silage corn and hay are the principal crops. Residential land is expanding in some areas as growth continues in the city of Burlington and adjacent communities.

THE WATERSHED PLAN

Studies by the Vermont Agency of Environmental Conservation (1977) and the SCS (1978) provided much of the information needed to develop the watershed protection plan. These studies identified the water quality problems of excessive sediment and phosphorus delivery into Shelburne Bay. Sources of these pollutants were determined to be excessive cropland erosion and the resulting sediment deposition, along with insufficient control of animal wastes.

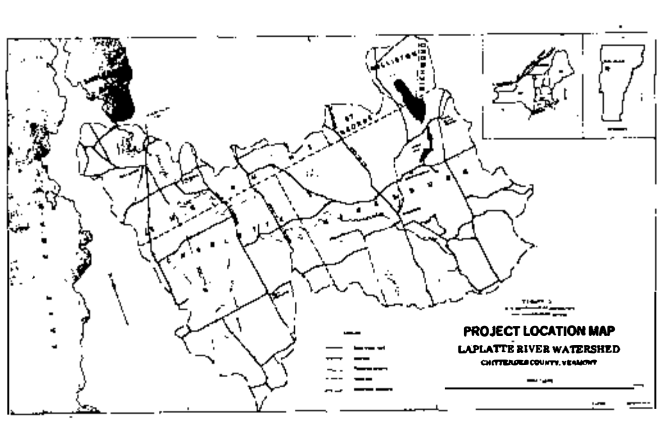

Figure 1.—Project location map. LaPlatte River Watershed.

To improve water quality in the LaPlatte River and Shelburne Bay, three goals were established:

1. Reduce the average annual rate of cropland erosion from 26 metric tons/ha (11.6 tons/acre) to 11 metric tons/ha (5 tons/acre).
2. Reduce annual sediment flow into Shelburne Bay from 7,830 metric tons (8,630 tons) to 4,280 metric tons (4,710 tons).
3. Reduce the amount of nutrients from manure reaching the LaPlatte River by increasing winter storage of manure from 7,300 metric tons (8,000 tons) to 32,000 metric tons (35,000 tons).

To meet these goals, SCS recommended developing conservation contracts for 41 farms. These contracts would call for conservation treatment of 1,070 ha (2,650 acres) of cropland, grassland, and forestland; installation of 30 animal waste storage facilities; and protection for 760 m (2,500 ft) of critically eroding streambank.

The plan described specific best management practices (BMP's) to be used, that is, those conservation practices considered most effective and practical for the desired pollution control. In addition, allowable rates of Federal cost-sharing were established for each BMP. Farmer participation in the program was strictly voluntary.

WATER QUALITY MONITORING AND ANALYSIS PLAN

The Water Quality Monitoring and Analysis plan was developed by the Vermont Water Resources Research Center, University of Vermont. This plan would evaluate the overall effectiveness of BMP's in improving surface water quality. The objectives of this program were (Soil Conserv. Serv. 1979):

1. To evaluate and document the impact of the watershed protection project on the export of sediment and nutrients from the LaPlatte River to Shelburne Bay;
2. To evaluate and document the reduction in the runoff of sediment, phosphorus, and animal wastes as a result of implementing particular BMP's; and
3. To provide a detailed analysis of the project useful to the long-term program needs of SCS and the Vermont Agency of Environmental Conservation.

To accomplish these objectives, river flow and water quality would be continuously monitored at five automated stations over 11 years; a series of other studies were designed to determine relationships between surface water quality and specific BMP's (Soil Conserv. Serv. 1979). The water quality monitoring plan is described in greater detail in another paper presented at this conference (Meals, 1985).

The plan identified monitoring site locations, water quality parameters to be measured, a schedule of operations, and responsibilities of cooperating agencies. This plan also established a Project Advisory Council consisting of representatives of all cooperating agencies. The Council meets quarterly to discuss programs and problems.

IMPLEMENTATION PROGRESS

Development of conservation contract agreements and BMP implementation began in 1980. As can be seen in Figure 2, all of the contract agreements and most of the BMP implementation occurred in the first 4 years. At present, 27 farms have signed contracts covering over 2,850 ha (7,000 acres). These farms control an estimated 70 percent of the animal wastes produced in the watershed. Most of these farms have installed various components of waste management systems and conservation cropping systems. Streambanks were protected on some farms. No new contracts are anticipated (Meals, 1984).

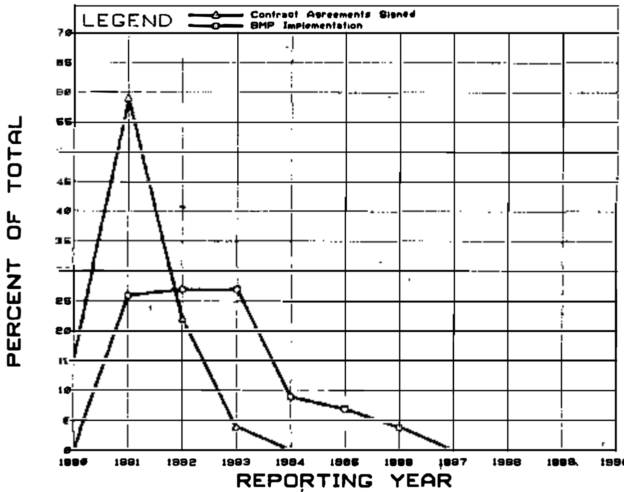

Figure 2.—Workload distribution by year. LaPlatte River Watershed project.

Analysis is underway to estimate the expected changes in average annual export of phosphorus and sediment.

Monitoring also began in 1980, although limited water quality data were collected during 1979. Except for amendments in study years 3 and 5, the monitoring and analysis program is proceeding as planned. In year 3, land use monitoring was intensified to produce the data needed to relate water quality changes to land use and land management changes (Meals and Cassell, 1982). In year 5, a special study was added to obtain more detailed information on nutrient and sediment export from barnyards, milkhouses, and manured haylands, with and without conservation treatment (Meals, 1984). All data collected since 1979 are being analyzed to detect water quality trends and relationships.

DISCUSSION

Watershed Protection Program. Osteen et al. (1981) recommended water-based land management for watersheds having severe water quality problems or where critical resources must be protected. Water-based land management often requires either monitoring or modeling to identify water quality problems and the sources and movement of the pollutants. The increased planning time results in better allocation of resources to improve the water quality.

The LaPlatte River Watershed plan was developed using water-based land management principles. The tools used to relate water quality changes to land management changes, however, were crude. The expected water quality changes were not well documented, especially for animal waste BMP's.

Experience, early monitoring results, and new research have refined these tools. Subsequent projects are using these new techniques to determine treatment alternatives and to choose farms for treatment. These techniques are described in another paper at this session (Keeler, 1985).

In the LaPlatte project, farms were earmarked for treatment as applications were received. The selection methods were somewhat subjective, and timing was a problem. Sometimes, because of a lag in application submittal, some medium-priority farms were serviced before higher-priority ones.

Pollutant control generally becomes more efficient and cost effective if the most severe sources are treated first. A thoroughly prepared water-based land management plan allows land management units to be ranked according to severity before project startup. Project funding can be contingent upon receiving enough high- to medium-prior-

Table 1.—Contract and implementation summary, LaPlatte River Watershed project.

	CONTRACTED		IMPLEMENTED				
			Waste Mgmt. Systems				
	No. of Farms	Hectares	Manure Storage	Barn-yards	Milk-houses	Conservation Cropping (ha)	Streambank Protection (m)
Totals to date	27	2,851	26	9	17	943	350
Projected	27	2,851	26	14	19	1,000	715

ity applications to ensure the desired water quality effects.

Regardless of the planning approach, an accelerated long-term program of this type will require more personnel than annual programs. This fact was evident in the La-Platte project as technical assistance needed from SCS increased during project implementation (Fig. 3). Furthermore, contract preparation demands extra time. As legal documents, contracts require attention to detail and multiple meetings with the landowner.

Technical personnel in such a project often have a wide range of knowledge and experience. Additional preproject training on water quality, the estimated influence of BMP's on pollutant transport, the preparation and legal aspects of contracts, and the design and installation of complex practices will result in a more efficient and effective program.

During project implementation, unanticipated situations and conditions are likely to arise. Continual assessment of project progress and problems is essential to avoid the recurrence of similar problems and to redirect activities if necessary (Natl. Water Qual. Eval. Proj. 1983). When the LaPlatte project began, administrative procedures were new to everyone. Problems with certain practice designs developed. However, administrative procedures are being continually streamlined. Designs have been improved. As a result, this project, as well as new projects, is proceeding with fewer problems.

Finally, it is very important to keep the public informed of progress (Natl. Water Qual. Eval. Proj. 1983). A project of this type arouses much public interest. Releasing progress reports to the public will help ensure public awareness, increase program participation, and aid in the administration of future projects.

Monitoring and Analysis Program. The Water Quality Monitoring and Analysis Program was fully operational a few months after the watershed protection program began. Some preproject water quality data were available from previous studies. These data, however, were collected for only 1 year, and station locations were not compatible with the current monitoring locations. Preproject–postproject comparisons are not possible. Data analysis and evaluation depend primarily on the observation of year-to-year trends in water quality. Climatic variability makes this a complex task, requiring long-term study. De-

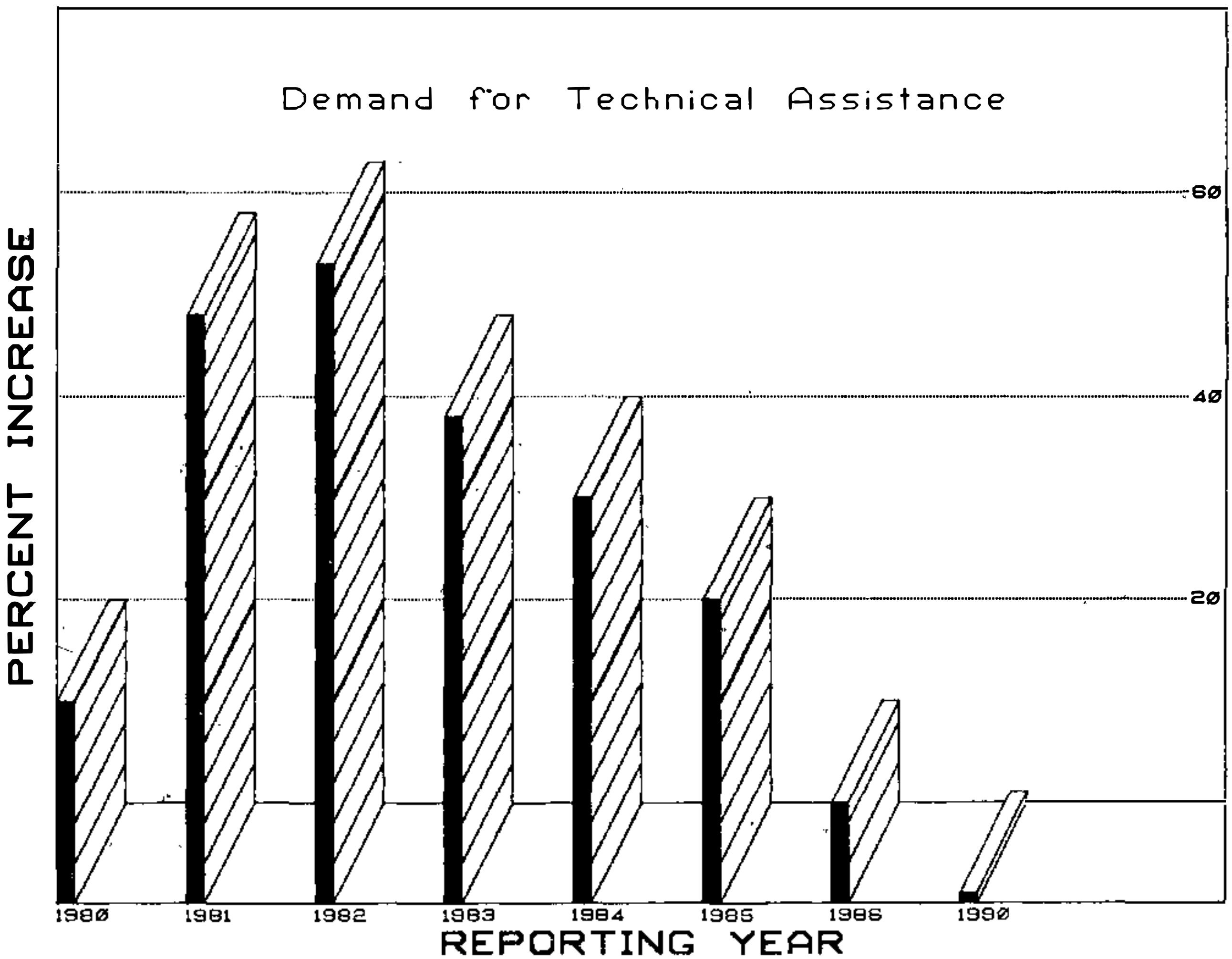

Figure 3.—Percent increase in demands for technical assistance resulting from the LaPlatte River Watershed project.

tailed preproject data would be desirable in future projects to more readily determine water quality changes.

A factor that has made trend analysis difficult in the LaPlatte project is the discharge from a municipal wastewater treatment facility. This point source discharge has complicated the interpretation of water quality trends at the main monitoring station, obscuring the nonpoint source water quality changes related to BMP implementation. Future projects designed to monitor these changes would benefit if monitoring were located in areas unaffected by point source discharges.

Another factor complicating the interpretation of water quality trends was the lack of detailed land use information. Though BMP implementation was carefully tracked, details on the time, location, and magnitude of farm activities were needed as well. Farmers were asked to record activities such as manure spreading, fertilizer application, plowing, and planting on a field-by-field basis. Collected twice each year, these data are being analyzed through a geographic information system (GIS), a specialized computer-based mapping overlay system for the analysis and display of spatial data. The use of detailed land use data in GIS is greatly improving the ability to correlate land use activities and water quality.

The large volume of information generated by the monitoring and analysis effort should be developed and put in practice in a manner consistent with the users' needs. It is essential that each cooperating agency commit at least one individual to the program. This person should be able to devote the time necessary to maintain good communications and actively participate in Project Advisory Council meetings. The Council has helped ensure that data collection and evaluation are proceeding desirably by providing a mechanism for program review, revision, and if necessary, redirection.

Finally, the monitoring program is intended to provide useful information both locally and nationally. The SCS national office has organized a task force to evaluate the project and to use the results to improve other such projects nationwide. Therefore, the wide dissemination of these results is assured.

SUMMARY AND CONCLUSIONS

The LaPlatte River Watershed was identified as the primary agricultural nonpoint source of pollution reaching Shelburne Bay, Lake Champlain. In 1979, the LaPlatte River Watershed project became the first land treatment only P.L. 83-566 project in the Nation. Both the ongoing program and future programs can benefit from this project.

Watershed Protection Program:

1. Develop detailed water-based land management plans using the best available data, models, and techniques.
2. Prioritize farms before initiating project.
3. Provide enough experienced personnel to conduct the program effectively.
4. Provide preproject training on water quality, pollutant transport, contract administration, and design and installation of complex practices.
5. Continually assess project progress and problems, and revise and redirect the program if necessary.
6. Keep the public informed.

Monitoring and Analysis Program:

1. Collect sample preproject data.
2. Consider locating new monitoring projects in areas unaffected by point source pollution.
3. Collect detailed land use data from the beginning of the project.
4. Organize a project advisory council and meet regularly.
5. Organize a task force to help disseminate monitoring results to advance new projects.

The LaPlatte River Watershed project is only 5 years old. Much has been learned, and surely much remains to be learned. However, the success of implementing this project and the opportunity to improve new projects is apparent. Watershed projects (P.L. 83-566) that involve only land treatment appear to be acceptable to decision-makers and the public as an effective approach to implementing agricultural nonpoint source pollution control practices.

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